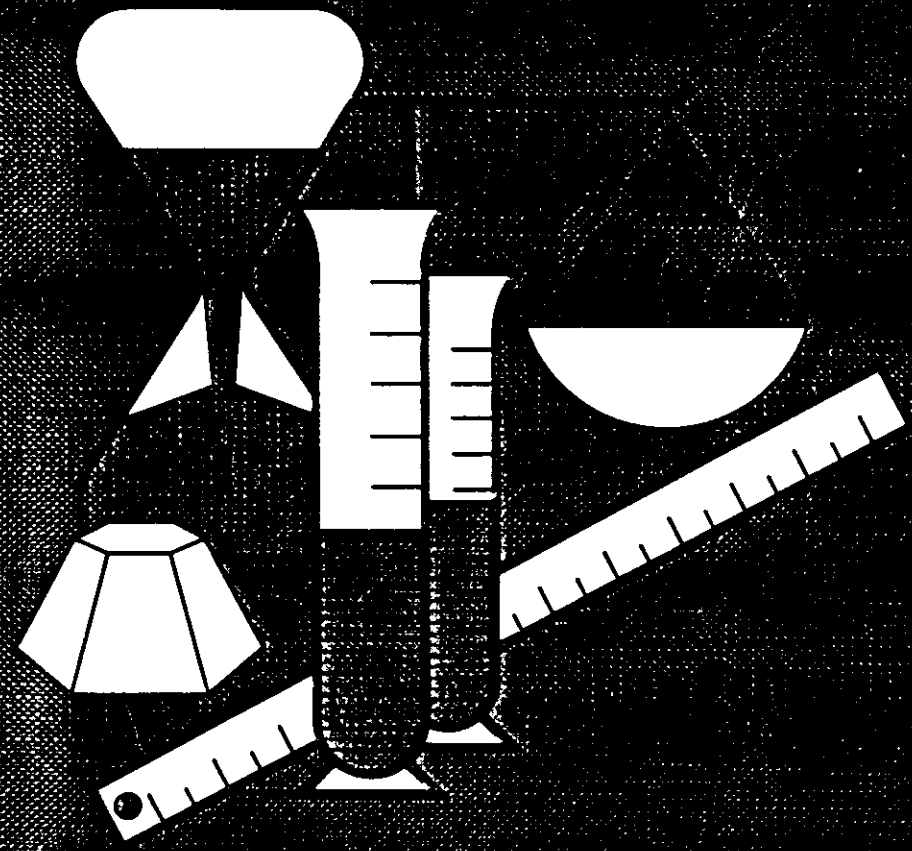
ISO STANDARDS HANDBOOK 2

Units of measurement



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ISO STANDARDS HANDBOOK 2 **1982**

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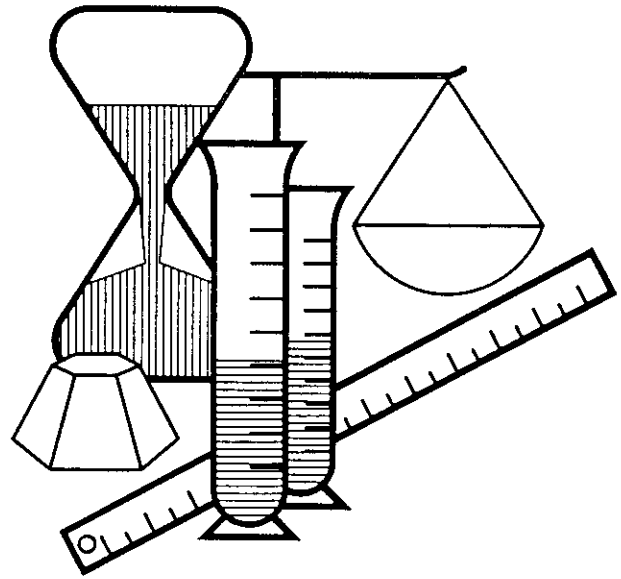

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ISO STANDARDS HANDBOOK 2

Units of measurement
Unités de mesure

Second edition 1982

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Introduction

The *Système international d'unités (SI)* is fast becoming the international technical language *par excellence*. Only a handful of countries are not yet metric or in the process of changing over to the metric system.

That is not to say that all is now neat and orderly, since many countries which have traditionally used metric measures still have to make a number of detailed adjustments to bring their practice wholly into line with the SI.

The present logical well-defined system is the result of international agreements taken at a succession of General Conferences of Weights and Measures. For a quarter of a century, ISO/TC 12, *Quantities, units, symbols, conversion factors and conversion tables*, has laboured to prepare a series of International Standards for physical quantities and units, their names and symbols, and has in this series of practical International Standards strongly recommended the unit system developed by the General Conference of Weights and Measures.

A number of other ISO technical committees have also developed standards on units and symbols with regard to the implementation of the SI in some particular technical fields. The following standards may be quoted as examples : ISO 2955-1974 (TC 97, *Computers and information processing*), ISO 4226-1980 (TC 146, *Air quality*), ISO 5651-1978 (TC 6, *Paper, board and pulps*), etc.

It is hoped that the publication of this handbook will contribute to the understanding and implementation of the SI throughout the world, and spread the use of the standardized names of physical quantities.

Explanatory notes

- At the time of going to press (January 1982), this handbook was up to date. However, standardization is a dynamic and continuous process and users should take into account the fact that published standards are subject to review and possible revision. It is pointed out that the only valid standard is the latest available edition. A convenient way to ensure that one is fully up to date in any given area is through the ISO subscription scheme, details of which are obtainable from the ISO Central Secretariat.

- The standards reproduced in this handbook have been photographically reduced from A4 size (210 mm × 297 mm) to A5 (148 mm × 210 mm).

- Certain information (such as the brief history of the standard and the voting results), which was not considered essential for the purpose of the handbook, is not included here. Wherever practicable, corrections and amendments to the standards have been incorporated in the texts.

- The standards are presented in numerical order.

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SI units and recommendations for the use of their multiples and of certain other units

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SI units and recommendations for the use of their multiples and of certain other units

1 Scope and field of application

This International Standard

a) describes the International System of Units[1] (in clauses 2 and 3);

b) recommends selected decimal multiples and sub-multiples of the SI units for general use and gives certain other units which may be used with the International System of Units (in clauses 4 and 5, and annex A);

c) defines base and supplementary SI units (in annex B).

2 SI Units

The name Système International d'Unités (International System of Units), with the international abbreviation SI, was adopted by the 11th Conférence Générale des Poids et Mesures in 1960.

This system includes three classes of units:

— base units

— supplementary units

— derived units,

which together form the coherent system of SI units.

1) Full information about the International System of Units is given in a publication from the International Bureau of Weights and Measures: *Le Système International d'Unités* (authorized English translations have been published in the United Kingdom through the National Physical Laboratory, and in the United States of America through the National Bureau of Standards).

2.1 Base units

The International System of Units is founded on the seven base units listed in table 1.

Table 1

Quantity	Name of base SI unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

For the definitions of the base units and the supplementary units, see annex B.

2.2 Supplementary units

The Conférence Générale des Poids et Mesures has not classified certain units of the International System under either base units or derived units.

These units, listed in table 2, are called "supplementary units" and may be regarded either as base units or as derived units.[1)]

Table 2

Quantity	Name of supplementary SI unit	Symbol
plane angle	radian	rad
solid angle	steradian	sr

2.3 Derived units

Derived units are expressed algebraically in terms of base units and/or supplementary units. Their symbols are obtained by means of the mathematical signs of multiplication and division; for example, the SI unit for velocity is metre per second (m/s) and the SI unit for angular velocity is radian per second (rad/s).

For some of the derived SI units, special names and symbols exist; those approved by the Conférence Générale des Poids et Mesures are listed in tables 3 and 4.

It may sometimes be advantageous to express derived units in terms of other derived units having special names; for example, the SI unit for electric dipole moment is usually expressed as C·m instead of A·s·m.

Table 3

Quantity	Special name of derived SI unit	Symbol	Expressed in terms of base or supplementary SI units or in terms of other derived SI units
frequency	hertz	Hz	$1\ Hz = 1\ s^{-1}$
force	newton	N	$1\ N = 1\ kg \cdot m/s^2$
pressure, stress	pascal	Pa	$1\ Pa = 1\ N/m^2$
energy, work, quantity of heat	joule	J	$1\ J = 1\ N \cdot m$
power	watt	W	$1\ W = 1\ J/s$
electric charge, quantity of electricity	coulomb	C	$1\ C = 1\ A \cdot s$
electric potential, potential difference, tension, electromotive force	volt	V	$1\ V = 1\ J/C$
electric capacitance	farad	F	$1\ F = 1\ C/V$
electric resistance	ohm	Ω	$1\ \Omega = 1\ V/A$
electric conductance	siemens	S	$1\ S = 1\ \Omega^{-1}$
flux of magnetic induction, magnetic flux	weber	Wb	$1\ Wb = 1\ V \cdot s$
magnetic flux density, magnetic induction	tesla	T	$1\ T = 1\ Wb/m^2$
inductance	henry	H	$1\ H = 1\ Wb/A$
Celsius temperature	degree Celsius	°C	$1\ °C = 1\ K$[2)]
luminous flux	lumen	lm	$1\ lm = 1\ cd \cdot sr$
illuminance	lux	lx	$1\ lx = 1\ lm/m^2$

Table 4 — Derived SI units with special names accepted for the sake of safeguarding human health

Quantity	Special name of derived SI unit	Symbol	Expressed in terms of base units or derived SI units
activity (of a radionuclide)	becquerel	Bq	$1\ Bq = 1\ s^{-1}$
absorbed dose, specific energy imparted, kerma, absorbed dose index	gray	Gy	$1\ Gy = 1\ J/kg$
dose equivalent	sievert	Sv	$1\ Sv = 1\ J/kg$

1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

2) For the use of degree Celsius (°C), see note 2 under the definition of kelvin in annex B.

3 Multiples of SI units

The prefixes given in table 5 (SI prefixes) are used to form names and symbols of multiples (decimal multiples and sub-multiples) of the SI units.

The symbol of a prefix is considered to be combined with the single unit symbol[1)] to which it is directly attached, forming with it a new symbol (for a decimal multiple or sub-multiple) which can be raised to a positive or negative power, and which can be combined with other unit symbols to form symbols for compound units.

Examples

$1\ cm^3 = (10^{-2}\ m)^3 = 10^{-6}\ m^3$

$1\ \mu s^{-1} = (10^{-6}\ s)^{-1} = 10^6\ s^{-1}$

$1\ mm^2/s = (10^{-3}\ m)^2/s = 10^{-6}\ m^2/s$

Compound prefixes shall not be used; for example, write nm (nanometre), never mμm.

NOTE — Because the name of the base unit for mass, kilogram, contains the name of the SI prefix "kilo", the names of the decimal multiples and sub-multiples of the unit of mass are formed by adding the prefixes to the word "gram", e.g. milligram (mg) instead of microkilogram (μkg).

Table 5

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

4 Use of the SI units and their multiples

4.1 The choice of the appropriate multiple (decimal multiple or sub-multiple) of an SI unit is governed by convenience, the multiple chosen for a particular application being the one which will lead to numerical values within a practical range.

4.2 The multiple can usually be chosen so that the numerical values will be between 0,1 and 1000.

Examples

$1{,}2 \times 10^4$ N	can be written as	12 kN
0,003 94 m	can be written as	3,94 mm
1401 Pa	can be written as	1,401 kPa
$3{,}1 \times 10^{-8}$ s	can be written as	31 ns

However, in a table of values for the same quantity or in a discussion of such values within a given context, it will generally be better to use the same multiple for all items, even when some of the numerical values will be outside the range 0,1 to 1000. For certain quantities in particular applications, the same multiple is customarily used; for example, the millimetre is used for dimensions in most mechanical engineering drawings.

4.3 It is recommended that only one prefix be used in forming a multiple of a compound SI unit.

4.4 Errors in calculations can be avoided more easily if all quantities are expressed in SI units, prefixes being replaced by powers of 10.

4.5 Rules for writing unit symbols

4.5.1 Unit symbols should be printed in roman (upright) type (irrespective of the type used in the rest of the text), should remain unaltered in the plural, should be written without a final full stop (period) except for normal punctuation, e.g. at the end of a sentence, and should be placed after the complete numerical value in the expression for a quantity, leaving a space between the numerical value and the unit symbol.

Unit symbols should generally be written in lower case letters except that the first letter is written in upper case when the name of the unit is derived from a proper name.

Examples

m metre
s second
A ampere
Wb weber

1) In this case, the term "unit symbol" means only a symbol for a base unit, a derived unit with a special name or a supplementary unit; see, however, the note about the base unit kilogram.

4.5.2 When a compound unit is formed by multiplication of two or more units, this may be indicated in one of the following ways:

N·m N.m N m

NOTE — The last form may also be written without a space, provided that special care is taken when the symbol for one of the units is the same as the symbol for a prefix, e.g. mN means millinewton, not metre newton.

When a compound unit is formed by dividing one unit by another, this may be indicated in one of the following ways:

$\frac{m}{s}$, m/s or by writing the product of m and s^{-1}, for example $m \cdot s^{-1}$.

In no case should more than one solidus (as in m/s) on the same line be included in such a combination unless parentheses be inserted to avoid all ambiguity. In complicated cases, negative powers or parentheses should be used.

5 Non SI units which may be used together with the SI units and their multiples

5.1 There are certain units outside the SI which are recognized by the Comité International des Poids et Mesures (CIPM) as having to be retained because of their practical importance (table 6) or for use in specialized fields (table 7).

5.2 Prefixes given in table 5 may be attached to many of the units given in tables 6 and 7; for example, millilitre, ml; megaelectronvolt, MeV. See also annex A, column 6.

5.3 In a limited number of cases, compound units are formed with the units given in tables 6 and 7 together with SI units and their multiples; for example, kg/h; km/h. See also annex A, columns 5 and 6.

Table 6

Quantity	Name of unit	Unit symbol	Definition
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min
	day	d	1 d = 24 h
plane angle	degree	°	$1° = (\pi/180)$ rad
	minute	′	$1′ = (1/60)°$
	second	″	$1″ = (1/60)′$
volume	litre	l, L[1]	$1 l = 1 dm^3$
mass	tonne	t	$1 t = 10^3$ kg

1) The two symbols for litre are on an equal footing. The CIPM will, however, before the 18th CGPM make a survey on the development of the use the two symbols in order to see if one of the two may be suppressed. [16th CGPM (1979), Resolution 6]

Table 7

Quantity	Name of unit	Unit symbol	Definition
energy	electronvolt	eV	1 electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 volt in vacuum; $1 eV = 1{,}602\ 19 \times 10^{-19}$ J (approximately)
mass of an atom	atomic mass unit	u	1 (unified) atomic mass unit is equal to the fraction 1/12 of the mass of an atom of the nuclide ^{12}C; $1 u = 1{,}660\ 57 \times 10^{-27}$ kg (approximately)
length	astronomic unit	AU[1]	1 AU = 149 597,870 × 10^6 m (adopted value in System of Astronomic Constants, 1979)
	parsec	pc	1 parsec is the distance at which 1 astronomic unit subtends an angle of 1 second of arc; 1 pc = 206 265 AU = 30 857 × 10^{12} m (approximately)
pressure of fluid	bar[2]	bar	1 bar = 10^5 Pa

1) The unit has no international symbol; AU is the abbreviation of the English name; the abbreviation of the French name is UA.

2) The bar is not mentioned by CIPM in this group of units; in many countries, however, there are special requirements for this unit.

Annex A

Examples of decimal multiples and sub-multiples of SI units and of some other units which may be used

For a number of commonly used quantities, examples of decimal multiples and sub-multiples of SI units, as well as of some other units which may be used, are given in this annex. It is suggested that the selection shown, while not intended to be restrictive, will none the less prove helpful in presenting values of quantities in an identical manner in similar contexts within the various sectors of technology. For some needs (for example, in applications in science and education), it is recognized that greater freedom will be required in the choice of decimal multiples and sub-multiples of SI units than is exemplified in the list which follows.

NOTE — Factors for conversion to SI units from the other units listed are given in the relevant parts of ISO 31.

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Part 1: **Space and time**						
1-1.1	angle (plane angle)	rad (radian)	mrad μrad	° (degree) ′ (minute) ″ (second)		If the radian is not used, the units degree or grade (or gon) may be used. Decimal subdivisions of degree are preferable to minute and second for most applications. grade (g) or gon, $1^g = 1 \text{ gon} = \frac{\pi}{200}$ rad
1-2.1	solid angle	sr (steradian)				
1-3.1...7	length	m (metre)	km cm mm μm nm pm fm			1 international nautical mile = 1 852 m
1-4.1	area	m^2	km^2 dm^2 cm^2 mm^2			ha (hectare), 1 ha = 10^4 m^2 a (are), 1 a = 10^2 m^2
1-5.1	volume	m^3	dm^3 cm^3 mm^3	l, L[1] (litre)	hl 1 hl = 10^{-1} m^3 cl 1 cl = 10^{-5} m^3 ml 1 ml = 10^{-6} m^3 = 1 cm^3	In 1964, the Conférence Générale des Poids et Mesures declared that the name litre (l) may be used as a special name for the cubic decimetre (dm^3) and advised against the use of the name litre for high-precision measurements.

1) See table 6.

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1-6.1	time	s (second)	ks ms µs ns	d (day) h (hour) min (minute)		Other units such as week, month and year (a) are in common use.
1-7.1	angular velocity	rad/s				
1-9.1	velocity	m/s			km/h 1 km/h = $\frac{1}{3,6}$ m/s	1 knot = 0,514 444 m/s
1-10.1	acceleration	m/s^2				
Part 2: Periodic and related phenomena						
2-3.1	frequency	Hz (hertz)	THz GHz MHz kHz			
2-3.2	rotational frequency	s^{-1}		min^{-1}		The designations "revolution per minute" (r/min) and "revolution per second" (r/s) are widely used for rotational frequency in specifications on rotating machinery.[1]
Part 3: Mechanics						
3-1.1	mass	kg (kilogram)	Mg g mg µg	t (tonne)		
3-2.1	density (mass density)	kg/m^3	Mg/m^3 or kg/dm^3 or g/cm^3	t/m^3 or kg/l	g/ml g/l	For litre, see item 1-5.1.
3-5.1	linear density	kg/m	mg/m			1 tex = 10^{-6} kg/m The unit tex is used for textile filaments.
3-7.1	momentum	kg·m/s				
3-8.1	moment of momentum, angular momentum	$kg·m^2/s$				
3-9.1	moment of inertia	$kg·m^2$				
3-10.1	force	N (newton)	MN kN mN µN			

1) See also IEC Publication 27-1 (1971).

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
3-12.1	moment of force	N·m	MN·m kN·m mN·m µN·m			
3-13.1	pressure	Pa (pascal)	GPa MPa kPa mPa µPa	bar[1]	mbar µbar	1 bar = 10^5 Pa
3-13.2	normal stress	Pa or N/m^2	GPa MPa or N/mm^2 kPa			
3-21.1	viscosity (dynamic)	Pa·s	mPa·s			P (poise)[2] 1 cP = 1 mPa·s
3-22.1	kinematic viscosity	m^2/s	mm^2/s			St (stokes)[2] 1 cSt = 1 mm^2/s
3-23.1	surface tension	N/m	mN/m			
3-24.1	energy, work	J (joule)	EJ PJ TJ GJ MJ kJ mJ	eV (electron-volt)	GeV MeV keV	The units W·h, kW·h, MW·h, GW·h and TW·h are used in the field of consumption of electrical energy. The units keV, MeV and GeV are used in atomic and nuclear physics and in accelerator technology.
3-25.1	power	W (watt)	GW MW kW mW µW			
Part 4: Heat						
4-1.1	thermodynamic temperature	K (kelvin)				
4-2.1	Celsius temperature	°C (degree Celsius)[3]				The Celsius temperature t is equal to the difference $t = T - T_0$ between two thermodynamic temperatures T and T_0, where T_0 = 273,15 K.
4-1.1 4-2.1	temperature interval	K				For temperature interval, °C may be used instead of K.

1) For the bar, see 5.1 and table 7.

2) Poise and stokes are special names for CGS units. They and their multiples should not be used together with SI units.

3) For the definition and the use of degree Celsius (°C), see note 2 under the definition of kelvin in annex B.

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4-3.1	linear expansion coefficient	K^{-1}				For degree Celsius, see footnote 3), page 7.
4-6.1	heat, quantity of heat	J	EJ PJ TJ GJ MJ kJ mJ			
4-7.1	heat flow rate	W	kW			
4-9.1	thermal conductivity	W/(m·K)				For degree Celsius, see footnote 3), page 7.
4-10.1	coefficient of heat transfer	W/(m²·K)				For degree Celsius, see footnote 3), page 7.
4-14.1	heat capacity	J/K	kJ/K			For degree Celsius, see footnote 3), page 7.
4-15.1	specific heat capacity	J/(kg·K)	kJ/(kg·K)			For degree Celsius, see footnote 3), page 7.
4-17.1	entropy	J/K	kJ/K			
4-18.1	specific entropy	J/(kg·K)	kJ/(kg·K)			
4-20.1	specific internal energy	J/kg	MJ/kg kJ/kg			
—	specific latent heat	J/kg	MJ/kg kJ/kg			
Part 5: Electricity and magnetism						
5-1.1	electric current	A (ampere)	kA mA μA nA pA			
5-2.1	electric charge, quantity of electricity	C (coulomb)	kC μC nC pC			1 A·h = 3,6 kC
5-3.1	volume density of charge, charge density	C/m^3	C/mm^3 MC/m^3 or C/cm^3 kC/m^3 mC/m^3 $\mu C/m^3$			

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5-4.1	surface density of charge	C/m^2	MC/m^2 or C/mm^2 C/cm^2 kC/m^2 mC/m^2 $\mu C/m^2$			
5-5.1	electric field strength	V/m	MV/m kV/m or V/mm V/cm mV/m μV/m			
5-6.1 5-6.2 5-6.3	electric potential potential difference (tension) electromotive force	V (volt)	MV kV mV μV			
5-7.1	electric flux density, displacement	C/m^2	C/cm^2 kC/m^2 mC/m^2 $\mu C/m^2$			
5-8.1	electric flux, (flux of displacement)	C	MC kC mC			
5-9.1	capacitance	F (farad)	mF μF nF pF			
5-10.1	permittivity	F/m	μF/m nF/m pF/m			
5-13.1	electric polarization	C/m^2	C/cm^2 kC/m^2 mC/m^2 $\mu C/m^2$			
5-14.1	electric dipole moment	C·m				
5-15.1	current density	A/m^2	MA/m^2 or A/mm^2 A/cm^2 kA/m^2			

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5-16.1	linear current density	A/m	kA/m or A/mm A/cm			
5-17.1	magnetic field strength	A/m	kA/m or A/mm A/cm			
5-18.1	magnetic potential difference	A	kA mA			
5-19.1	magnetic flux density, magnetic induction	T (tesla)	mT μT nT			
5-20.1	magnetic flux	Wb (weber)	mWb			
5-21.1	magnetic vector potential	Wb/m	kWb/m or Wb/mm			
5-22.1 5-22.2	self inductance mutual inductance	H (henry)	mH μH nH pH			
5-24.1	permeability	H/m	μH/m nH/m			
5-27.1	electromagnetic moment, (magnetic moment)	$A \cdot m^2$				
5-28.1	magnetization	A/m	kA/m or A/mm			
5-29.1	magnetic polarization	T	mT			
(IEC Pub. 27, item 86)	magnetic dipole moment	$N \cdot m^2/A$ or Wb·m				
5-33.1	resistance (to direct current)	Ω (ohm)	GΩ MΩ kΩ mΩ μΩ			
5-34.1	conductance (to direct current)	S (siemens)	kS mS μS			

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5-35.1	resistivity	Ω·m	GΩ·m MΩ·m kΩ·m Ω·cm mΩ·m μΩ·m nΩ·m			$\mu\Omega \cdot cm = 10^{-8}\ \Omega \cdot m$ $\frac{\Omega \cdot mm^2}{m} = 10^{-6}\ \Omega \cdot m = \mu\Omega \cdot m$ are also used.
5-36.1	conductivity	S/m	MS/m kS/m			
5-37.1	reluctance	H^{-1}				
5-38.1	permeance	H				
5-41.1 5-41.2 5-41.3 5-41.4	impedance (complex impedance) modulus of impedance, (impedance) reactance resistance	Ω	MΩ kΩ mΩ			
5-43.1 5-43.2 5-43.3 5-43.4	admittance (complex admittance) modulus of admittance, (admittance) susceptance conductance	S	kS mS μS			
5-44.1	power	W	TW GW MW kW mW μW nW			In electric power technology, active power is expressed in watts (W), apparent power in voltamperes (V·A) and reactive power in vars (var).
Part 6: Light and related electromagnetic radiations						
6-3.1	wavelength	m	μm nm pm			Å (ångström), $1\ Å = 10^{-10}\ m = 0{,}1\ nm = 10^{-4}\ \mu m$
6-6.1	radiant energy	J				
6-9.1	radiant power, radiant energy flux	W				
6-11.1	radiant intensity	W/sr				
6-12.1	radiance	$W/(sr \cdot m^2)$				
6-13.1	radiant exitance	W/m^2				

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
6-14.1	irradiance	W/m^2				
6-19.1	luminous intensity	cd (candela)				
6-20.1	luminous flux	lm (lumen)				
6-21.1	quantity of light	lm·s				1 lm·h = 3 600 lm·s
6-22.1	luminance	cd/m^2				
6-23.1	luminous exitance	lm/m^2				
6-24.1	illuminance	lx (lux)				
6-25.1	light exposure	lx·s				
6-26.1	luminous efficacy	lm/W				
Part 7: **Acoustics**						
7-1.1	period periodic time	s	ms µs			
7-2.1	frequency	Hz	MHz kHz			
7-5.1	wavelength	m	mm			
7-7.1	density (mass density)	kg/m^3				
7-8.1 7-8.2	static pressure (instantaneous) sound pressure	Pa	mPa µPa			
7-10.1	(instantaneous) sound particle velocity	m/s	mm/s			
7-12.1	(instantaneous) volume flow rate, volume velocity	m^3/s				
7-13.1	velocity of sound	m/s				
7-15.1	sound energy flux, sound power	W	kW mW µW pW			
7-16.1	sound intensity	W/m^2	mW/m^2 $µW/m^2$ pW/m^2			

Item No. in ISO 31	Quantity	SI unit	Selection of multiples of the SI unit	Units outside the SI which are nevertheless recognized by the CIPM as having to be retained either because of their practical importance or because of their use in specialized fields		Remarks, and information about units used in special fields
				Units	Multiples of units given in column 5	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
7-17.2	specific acoustic impedance	Pa·s/m				
7-18.1	acoustic impedance	$Pa·s/m^3$				
7-19.1	mechanical impedance	N·s/m				
7-20.1	sound pressure level					dB (decibel)
7-21.1	sound power level					dB
7-27.1	sound reduction index, sound transmission loss					dB
7-28.1	equivalent absorption area of a surface or object	m^2				
7-29.1	reverberation time	s				
Part 8: **Physical chemistry and molecular physics**						
8-3.1	amount of substance	mol (mole)	kmol mmol µmol			
8-5.1	molar mass	kg/mol	g/mol			
8-6.1	molar volume	m^3/mol	dm^3/mol cm^3/mol	l/mol		For litre, see item 1-5.1.
8-7.1	molar internal energy	J/mol	kJ/mol			
8-8.1	molar heat capacity	J/(mol·K)				
8-9.1	molar entropy	J/(mol·K)				
8-13.1	concentration of substance B, amount-of-substance concentration of substance B	mol/m^3	mol/dm^3 or $kmol/m^3$	mol/l		For litre, see item 1-5.1.
8-16.1	molality of solute substance B	mol/kg	mmol/kg			
8-38.1	diffusion coefficient	m^2/s				
8-40.1	thermal diffusion coefficient	m^2/s				

Annex B

Definitions of the base units and supplementary units of the International System of Units

Base units

metre: The metre is the length equal to 1 650 763,73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.

[11th CGPM (1960), Resolution 6]

kilogram: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

[1st CGPM (1889) and 3rd CGPM (1901)]

second: The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.

[13th CGPM (1967), Resolution 1]

ampere: The ampere is that constant electric current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

[CIPM (1946), Resolution 2 approved by the 9th CGPM (1948)]

kelvin: The kelvin, unit of thermodynamic temperature, is the fraction 1/273,16 of the thermodynamic temperature of the triple point of water.

[13th CGPM (1967), Resolution 4]

NOTES

1 The 13th CGPM (1967, Resolution 3) also decided that the unit kelvin and its symbol K should be used to express an interval or a difference of temperature.

2 In addition to the thermodynamic temperature (symbol T), expressed in kelvins, use is also made of Celsius temperature (symbol t) defined by the equation $t = T - T_0$, where $T_0 = 273{,}15$ K by definition. The unit "degree Celsius" is equal to the unit "kelvin", but "degree Celsius" is a special name in place of "kelvin" for expressing Celsius temperature. A temperature interval or a Celsius temperature difference can be expressed in degrees Celsius as well as in kelvins.

mole: The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0,012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

[14th CGPM (1971), Resolution 3]

candela: The candela is the luminous intensity in a given direction of a source which emits monochromatic radiation of frequency 540×10^{12} hertz and of which the radiant intensity in that direction is 1/683 watt per steradian.

[16th CGPM (1979), Resolution 3]

Supplementary units

radian: The radian is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.

[ISO 31/1-1978]

steradian: The steradian is the solid angle which, having its vertex in the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

[ISO 31/1-1978]

General principles concerning quantities, units and symbols

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General principles concerning quantities, units and symbols

0 Introduction

The scope of Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors and conversion tables*, is standardization of units and symbols for quantities and units (and mathematical symbols) used within the different fields of science and technology, giving, where necessary, definitions of these quantities and units. In fulfilment of this responsibility, ISO/TC 12 has prepared ISO 31, which contains the following parts :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

1 Scope and field of application

The purpose of this International Standard is to give general information about principles concerning physical quantities, equations, quantity and unit symbols, and coherent unit systems, especially the International System of Units, SI.

The principles laid down in this International Standard are intended for general use within the various fields of science and technology and as a general introduction to the other International Standards in the ISO 31 series.

2 Quantities and units

2.1 Physical quantity, unit and numerical value

Physical quantities are used for the quantitative description of physical phenomena. Quantities may be grouped together into categories of quantities which are mutually comparable. Lengths, diameters, distances, heights, wavelengths and so on would constitute such a category.

If a particular example of a quantity out of such a category is chosen as a reference quantity called *the unit*, then any other quantity from this category can be expressed in terms of this unit, as a product of this unit and a number. This number is called the *numerical value* of the quantity expressed in this unit.

Example : The wavelength of one of the sodium lines is

$$\lambda = 5{,}896 \times 10^{-7}\ \text{m}$$

Here λ is the symbol for the physical quantity : wavelength; m is the symbol for the unit of length : metre; and $5{,}896 \times 10^{-7}$ is the numerical value of the wavelength expressed in metres.

In formal treatments of quantities and units, this relationship may be expressed in the form

$$A = \{A\} \cdot [A]$$

where A is the symbol for the physical quantity, $[A]$ the symbol for the unit and $\{A\}$ symbolizes the numerical value of the quantity A expressed in the unit $[A]$. For vectors and tensors the components are quantities which may be expressed as described above.

If a quantity is expressed in another unit, which is k times smaller, then the new numerical value becomes k times larger : the product of the numerical value and the unit is independent of the unit.

Example : Changing the unit for the wavelength from the metre to the nanometre, which is 10^9 times smaller, leads to a numerical value which is 10^9 times larger.

Thus,

$$\lambda = 5{,}896 \times 10^{-7}\ \text{m} = 5{,}896 \times 10^{-7} \times 10^{9}\ \text{nm} = 589{,}6\ \text{nm}$$

Remark on notation for numerical values

It is essential to distinguish between the quantity itself and the numerical value of the quantity expressed in a particular unit. The numerical value of a quantity expressed in a particular unit could be indicated by placing curly brackets around the quantity symbol and using the unit symbol as a subscript. It is, however, preferable to indicate the numerical value explicitly as the ratio of the quantity to the unit.

Example : $\lambda/\text{nm} = 589{,}6$ or $\{\lambda\}_{\text{nm}} = 589{,}6$

2.2 Quantities and equations

2.2.1 Mathematical operations with quantities

Two or more physical quantities cannot be added or subtracted unless they belong to the same category of mutually comparable quantities.

Physical quantities are multiplied or divided by one another according to the rules of algebra; the product of two quantities, A and B, satisfies the relation

$$AB = \{A\}\,\{B\}\cdot[A]\,[B]$$

Thus, the product $\{A\}\,\{B\}$ is the numerical value $\{AB\}$ of the quantity AB, and the product $[A]\,[B]$ is the unit $[AB]$ of the quantity AB.

Example : The velocity v of a particle in uniform motion is

$$v = l/t$$

where l is the distance travelled in the time-interval t.

Thus, if the particle traverses a distance $l = 6$ m in the time interval $t = 2$ s, the velocity v is equal to

$$v = \frac{l}{t} = \frac{6\ \text{m}}{2\ \text{s}} = 3\,\frac{\text{m}}{\text{s}}$$

The arguments of exponential, logarithmic and trigonometric functions, etc., are numbers, numerical values or dimensionless combinations of quantities (see 2.2.6).

Examples : $\exp(W/kT)$, $\ln(p/\text{kPa})$, $\sin(\omega t)$

2.2.2 Equations between quantities and equations between numerical values

Two types of equations are used in science and technology : *equations between quantities* in which a letter symbol denotes the totality of the physical quantity (i.e. numerical value × unit), and *equations between numerical values*. The equations between numerical values depend on the choice of the units, whereas the equations between quantities have the advantage of being independent of this choice. Therefore the use of equations between quantities should normally be preferred.

Example : A simple equation between quantities is

$$v = l/t$$

as given in 2.2.1.

Using, for example, kilometres per hour, metres and seconds as units for velocity, length and time, respectively, we may derive the following equation between numerical values

$$\{v\}_{\text{km/h}} = 3{,}6\{l\}_{\text{m}}/\{t\}_{\text{s}}$$

The number 3,6 which occurs in this equation results from the particular units chosen; with other choices it would generally be different.

If in this equation the subscripts, indicating the unit symbols, are omitted, one obtains

$$\{v\} = 3{,}6\{l\}/\{t\},$$

an equation between numerical values which is no longer independent of the choice of the units and is therefore not recommended for use.

In equations between numerical values, the units used should always be indicated.

2.2.3 Empirical constants

An empirical relation is often expressed in the form of an equation between the numerical values of certain physical quantities. Such a relation depends on the units in which the various physical quantities are expressed.

An empirical relation between numerical values can be transformed into an equation between physical quantities, containing one or more empirical constants. Such an equation between physical quantities has the advantage that the form of the equation is independent of the choice of the units. The numerical values of the empirical constants occurring in such an equation depend, however, on the units in which they are expressed, as is the case with other physical quantities.

Example : The results of measuring the length l and the periodic time T at a certain station, for each of several pendulums, can be represented by one quantity equation

$$T = C \cdot l^{1/2}$$

where the empirical constant C is found to be

$$C = 2{,}006\ \text{s/m}^{1/2}$$

(Theory shows that $C = 2\pi g^{-1/2}$, where g is the local acceleration of free fall.)

2.2.4 Numerical factors in quantity equations

The equations between quantities sometimes contain *numerical factors*. The numerical factors depend on the definitions chosen for the quantities occurring in the equations.

Examples :

1 The kinetic energy of a particle of mass m and velocity v is

$$E_k = \frac{1}{2} mv^2$$

2 The capacitance of a sphere with radius r in a medium of permittivity ε is

$$C = 4\pi\varepsilon r$$

2.2.5 Systems of quantities and equations between quantities; base quantities and derived quantities

Physical quantities are related to one another through equations that express laws of nature and/or define new quantities.

For the purpose of defining unit systems and introducing the concept of dimensions, it is convenient to consider some quantities as mutually independent, i.e. to regard these as *base quantities*, in terms of which the other quantities can be defined or expressed by means of equations; the latter quantities are called *derived quantities*.

It is a matter of choice how many and which quantities are considered to be base quantities.

The whole set of physical quantities included in ISO 31, parts 1 to 13 may be considered as being founded on seven base quantities : length, mass, time, electric current, temperature, amount of substance and luminous intensity.

In the field of mechanics a system of quantities and equations founded on three base quantities is generally used. In ISO 31, part 3, the base quantities used are length, mass and time.

In the field of electricity and magnetism a system of quantities and equations founded on four base quantities is generally used. In ISO 31, part 5, the base quantities used are length, mass, time and electric current.

In the same field, however, systems founded on only three base quantities, length, mass and time, have been widely used. Of these the so-called "Gaussian" or symmetric system is still in use. It is described in ISO 31, part 5, annex A.

2.2.6 Dimension of a quantity

Any quantity Q can be expressed in terms of other quantities by means of an equation. The expression may consist of a sum of terms. Each of these terms can be expressed as a product of powers of base quantities A, B, C,..., from a chosen set, sometimes multiplied by a numerical factor ξ, i.e.

$\xi A^{\alpha} B^{\beta} C^{\gamma}\ldots$, where the set of exponents $(\alpha, \beta, \gamma,\ldots)$ is the same for each term.

The *dimension* of the quantity Q is then expressed by the dimensional product

$$\dim Q = \mathsf{A}^{\alpha}\,\mathsf{B}^{\beta}\,\mathsf{C}^{\gamma}\ldots$$

where A, B, C,..., denote the dimensions of the base quantities A, B, C,..., and where $\alpha, \beta, \gamma,\ldots$, are called the *dimensional exponents*.

A quantity all of whose dimensional exponents are equal to zero is called a *dimensionless quantity*. Its dimensional product or dimension is $A^0 B^0 C^0 = 1$.

Example : When the dimensions of the three base quantities length, mass and time are denoted by L, M and T respectively, the dimension of the quantity work is expressed by $\dim W = \mathsf{L}^2\mathsf{M}\mathsf{T}^{-2}$, and the dimensional exponents are 2, 1 and −2.

In the system founded on the seven base quantities length, mass, time, electric current, temperature, amount of substance and luminous intensity, the base dimensions may be denoted by L, M, T, I, Θ, N and J respectively and the dimension of a quantity Q becomes in general

$$\dim Q = \mathsf{L}^{\alpha}\,\mathsf{M}^{\beta}\,\mathsf{T}^{\gamma}\,\mathsf{I}^{\delta}\,\Theta^{\varepsilon}\,\mathsf{N}^{\zeta}\,\mathsf{J}^{\eta}$$

Examples :

Quantity	*Dimension*
velocity	$\mathsf{L}\mathsf{T}^{-1}$
angular velocity	T^{-1}
force	$\mathsf{L}\mathsf{M}\mathsf{T}^{-2}$
energy	$\mathsf{L}^2\mathsf{M}\mathsf{T}^{-2}$
entropy	$\mathsf{L}^2\mathsf{M}\mathsf{T}^{-2}\Theta^{-1}$
electric potential	$\mathsf{L}^2\mathsf{M}\mathsf{T}^{-3}\mathsf{I}^{-1}$
permittivity	$\mathsf{L}^{-3}\mathsf{M}^{-1}\mathsf{T}^{4}\mathsf{I}^{2}$
magnetic flux	$\mathsf{L}^2\mathsf{M}\mathsf{T}^{-2}\mathsf{I}^{-1}$
illuminance	$\mathsf{L}^{-2}\mathsf{J}$
molar entropy	$\mathsf{L}^2\mathsf{M}\mathsf{T}^{-2}\Theta^{-1}\mathsf{N}^{-1}$
Faraday constant	$\mathsf{T}\mathsf{I}\mathsf{N}^{-1}$
relative density	1

In ISO 31, the dimensions of the quantities are not explicitly stated, except when the quantity is dimensionless.

2.3 Units

2.3.1 Coherent unit systems

Units might be chosen arbitrarily, but making an independent choice of a unit for each quantity would lead to the appearance of additional numerical factors in the equations between the numerical values.

It is possible, however, and in practice more convenient, to choose a system of units in such a way that the equations between numerical values have exactly the same form (including the numerical factors), as the corresponding equations between the quantities. A unit system defined in this way is called *coherent* with respect to the system of quantities and equations in question. The SI is such a system.

For a particular system of quantities and equations, a coherent system of units is obtained by first defining units for the base

quantities, the *base units*. Then for each derived quantity, the definition of the corresponding *derived unit* in terms of the base units is given by an algebraic expression obtained from the dimensional product (see 2.2.6), by replacing the symbols for the base dimensions by those of the base units. In such a coherent unit system no numerical factor other than the number 1 ever occurs in the expressions for the derived units in terms of the base units.

Examples :

Quantity	*Equation*	*Dimension*	*Symbol for derived unit*
velocity	$v = dl/dt$	LT^{-1}	m/s
force	$F = md^2l/dt^2$	MLT^{-2}	$kg \cdot m/s^2$
kinetic energy	$E_k = \frac{1}{2}mv^2$	ML^2T^{-2}	$kg \cdot m^2/s^2$
potential energy	$E_p = mgh$	ML^2T^{-2}	$kg \cdot m^2/s^2$
energy	$E = \frac{1}{2}mv^2 + mgh$	ML^2T^{-2}	$kg \cdot m^2/s^2$

2.3.2 SI units and their decimal multiples and submultiples

The name Système International d'Unités (International System of Units), with the international abbreviation SI was adopted by the 11th Conférence Générale des Poids et Mesures (CGPM) in 1960.

This system includes three classes of units :

base units
supplementary units
derived units

which together form the coherent system of *SI units*.

BASE UNITS

Quantity	*Name of base unit*	*Unit symbol*
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

SUPPLEMENTARY UNITS

Quantity	*Name of supplementary unit*	*Unit symbol*
plane angle	radian	rad
solid angle	steradian	sr

The CGPM has classified the SI units, radian and steradian, as "supplementary units", leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.(1)

In ISO 31, plane angle and solid angle are treated as derived quantities, defined as ratios of two lengths and of two areas respectively, and consequently are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

DERIVED UNITS

The expressions for the coherent derived units in terms of the base units can be obtained from the dimensional products by using the following formal substitutions :

L→m	I→A
M→kg	Θ→K
T→s	N→mol
	J→cd

Since in ISO 31 plane angle and solid angle are treated as derived quantities, the supplementary units radian and steradian will not occur in the expressions for the coherent derived units. Nevertheless, as indicated in the examples below, they may be introduced for convenience. This is particularly relevant in photometry (see ISO 31, part 6).

Examples :

Quantity	*Symbol for SI unit expressed in terms of the 7 base units (and the supplementary units in some cases)*
velocity	m/s
angular velocity	s^{-1} or rad/s
force	$kg \cdot m/s^2$
energy	$kg \cdot m^2/s^2$
entropy	$kg \cdot m^2/(s^2 \cdot K)$
electric potential	$kg \cdot m^2/(s^3 \cdot A)$
permittivity	$A^2 \cdot s^4/(kg \cdot m^3)$
magnetic flux	$kg \cdot m^2/(s^2 \cdot A)$
illuminance	$cd \cdot sr/m^2$
molar entropy	$kg \cdot m^2/(s^2 \cdot K \cdot mol)$
Faraday constant	$A \cdot s/mol$
relative density	1

For some of the derived units, special names and symbols have been adopted by the CGPM, e.g. joule (J) and volt (V) for the SI units for energy and electric potential respectively. It is often of advantage to use these special names and symbols. (For a complete list of special names for derived SI units, see ISO 1000.)

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

Examples :

1 Using the derived unit joule ($1\ J = 1\ m^2 \cdot kg \cdot s^{-2}$), one may write

Quantity	*Symbol for SI unit*
molar entropy	$J \cdot K^{-1} \cdot mol^{-1}$
magnetic flux	$J \cdot A^{-1}$

2 Using the derived unit volt ($1\ V = 1\ m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$), one may write

Quantity	*Symbol for SI unit*
magnetic flux	V·s
permittivity	$s \cdot A \cdot m^{-1} \cdot V^{-1}$

SI PREFIXES

In order to avoid large or small numerical values, decimal multiples and submultiples of the SI units are added to the coherent system within the framework of the International System of units. They are formed by means of the following prefixes (SI prefixes) :

Factor	*Prefix*	*Symbol*
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

For information about the use of the prefixes, see 3.2.4.

The SI units and their decimal multiples and submultiples formed by use of the prefixes are specially recommended.

2.3.3 Other unit systems and miscellaneous units

The CGS system of mechanical units is a coherent system the base units of which are

centimetre
gram
second

for the three base quantities length, mass and time.

In practice this system was enlarged by adding the kelvin, the candela and the mole as base units for the base quantities temperature, luminous intensity and amount of substance.

Electric and magnetic units have been defined in the CGS system in several ways depending on the system of quantities and equations chosen. Still in use is the "Gaussian" or symmetric CGS system, coherent with the "Gaussian" or symmetric system of quantities and equations founded on three base quantities. For further information on this system, see ISO 31, part 5, annex A.

The special names and symbols for derived CGS units such as dyne, erg, poise, stokes, gauss, oersted and maxwell *should not be used together with the SI.*

In other parts of ISO 31, the special names for the derived CGS units are given in annexes which are not integral parts of the standards.

Other coherent systems of units have been defined, e.g. a system based on the units foot, pound and second and a system based on the units metre, kilogram-force and second.

Apart from these, other units have been defined which do not belong to any coherent system, e.g. the atmosphere, the nautical mile and the curie.

There are certain units outside the SI which are recognized by the Comité International des Poids et Mesures (CIPM) as having to be retained for use together with the SI, e.g. minute, hour and electronvolt. For further information about these units, see ISO 1000.

3 Recommendations for printing symbols and numbers

3.1 Symbols for quantities

3.1.1 Symbols

The symbols for quantities are generally single letters of the Latin or Greek alphabet, sometimes with subscripts or other modifying signs. These symbols are printed in italic (sloping) type (irrespective of the type used in the rest of the text).

The symbol is not followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

NOTES

1 Symbols for vectorial and other non-scalar quantities are given in ISO 31, part 11, on mathematical signs and symbols.

2 Exceptionally, symbols made up of two letters are sometimes used for the dimensionless combinations of quantities (e.g. Reynolds number : *Re*). If such a two-letter symbol appears as a factor in a product, it is recommended that it be separated from the other symbols.

3.1.2 Rules for the printing of subscripts

When, in a given context, different quantities have the same letter symbol or when, for one quantity, different applications or different values are of interest, a distinction can be made by use of subscripts.

The following principles for the printing of subscripts are recommended :

A subscript that represents a symbol for a physical quantity is printed in italic (sloping) type.

Other subscripts are printed in roman (upright) type.

Examples :

Upright subscripts		*Sloping subscripts*	
C_g	(g : gas)	p	in C_p
g_n	(n : normal)	n	in $\Sigma_n a_n \theta_n$
μ_r	(r : relative)	x	in $\Sigma_x a_x b_x$
E_k	(k : kinetic)	i, k	in g_{ik}
χ_e	(e : electric)	x	in p_x
$d_{1/2}$		λ	in I_λ
c_{HCl}			

NOTES

1 Numbers as subscripts shall be printed in roman (upright) type. However, letter symbols representing numbers are generally printed in italic (sloping) type.

2 For use of subscripts, see also special remarks to ISO 31, parts 6 and 10.

3.1.3 Combination of symbols for quantities; elementary operations with quantities

When symbols for quantities are combined in a product, this process of combination may be indicated in one of the following ways :

ab, $a\ b$, $a \cdot b$, $a.b$, $a \times b$

NOTES

1 In some fields, distinction is made between $a \cdot b$ and $a \times b$.

2 For multiplication of numbers, see 3.3.3.

Division of one quantity by another may be indicated in one of the following ways :

$\frac{a}{b}$, a/b or by writing the product of a and b^{-1},
e.g. $a \cdot b^{-1}$

The procedure can be extended to cases where the numerator or the denominator, or both, are themselves products or quotients, but in no case should more than one solidus (/) on the same line be included in such a combination unless parentheses be inserted to avoid all ambiguity.

Examples :

$\frac{ab}{c} = ab/c = abc^{-1}$

$\frac{a/b}{c} = (a/b)/c = ab^{-1}c^{-1}$; but not $a/b/c$;

however, $\frac{a/b}{c/d} = \frac{ad}{bc}$

$\frac{a}{bc} = a/bc = a/(b \cdot c)$

The solidus can be used in cases where the numerator and the denominator involve addition or subtraction provided parentheses (or brackets or braces) be employed.

Examples :

$(a + b)/(c + d)$ means $\frac{a + b}{c + d}$;
the parentheses are required.

$a + b/c + d$ means $a + \frac{b}{c} + d$;
misunderstanding may, however, be avoided by writing it as $a + (b/c) + d$

Parentheses should also be used to remove ambiguities which may arise from the use of certain other signs and symbols for mathematical operations.

3.2 Names and symbols for units

3.2.1 International symbols for units

When international symbols for units exist, they, and no other, shall be used. They should be printed in roman (upright) type (irrespective of the type used in the rest of the text), should remain unaltered in the plural, should be written without a final full stop (period) except for normal punctuation, e.g. at the end of a sentence, and be placed after the complete numerical value in the expression for a quantity, leaving a space between the numerical value and the unit symbol.

The unit symbols should in general be printed in lower case letters except that the first letter is printed in upper case when the name of the unit is derived from a proper name.

Examples :

m metre
s second
A ampere
Wb weber

3.2.2 Combination of symbols for units

When a compound unit is formed by multiplication of two or more units, this may be indicated in one of the following ways :

N·m N.m N m

NOTE — The last form may also be written without a space provided that special care is taken when the symbol for one of the units is the same as the symbol for a prefix.

Example : mN means millinewton, not metre newton.

When a compound unit is formed by dividing one unit by another, this may be indicated in one of the following ways :

$\frac{\text{m}}{\text{s}}$, m/s or by writing the product of m and s^{-1},
e.g. $\text{m} \cdot \text{s}^{-1}$

In no case should more than one solidus (/) on the same line be included in such a combination unless parentheses are inserted

to avoid all ambiguity. In complicated cases negative powers or parentheses should be used.

3.2.3 Printing of symbols for units

No recommendation is made or implied about the font of upright type in which symbols for units are to be printed.

NOTE — In this series of publications the font used in such cases happens generally to be that of the associated text, but this does not constitute a recommendation.

3.2.4 Printing and use of prefixes

Symbols for prefixes should be printed in roman (upright) type without space between the symbol for the prefix and the symbol for the unit.

Compound prefixes shall not be used.

Example : Write nm (nanometre), never mμm.

The symbol of a prefix is considered to be combined with the single unit symbol to which it is directly attached, forming with it a new symbol (for a decimal multiple or submultiple) which can be raised to a positive or negative power, and which can be combined with other unit symbols to form symbols for compound units (see 3.2.2).

Examples :

$1\ \text{cm}^3 = (10^{-2}\ \text{m})^3 = 10^{-6}\ \text{m}^3$

$1\ \mu\text{s}^{-1} = (10^{-6}\ \text{s})^{-1} = 10^{6}\ \text{s}^{-1}$

$1\ \text{kA/m} = (10^{3}\ \text{A})/\text{m} = 10^{3}\ \text{A/m}$

NOTE — Because the name of the base unit for mass, kilogram, contains the name of the SI prefix "kilo", the names of the decimal multiples and submultiples of the unit of mass are formed by adding the prefixes to the word "gram"; for example, milligram (mg) instead of microkilogram (μkg).

3.2.5 Spelling of names of units

Where there are differences in the spelling of names of units within the English language, the spelling as given in the Oxford English Dictionary is used in the English-language versions of ISO 31, parts 0 to 13. This does not imply a preference over the spellings used in other English-speaking countries.

3.3 Numbers

3.3.1 Printing of numbers

Numbers should generally be printed in roman (upright) type.

To facilitate the reading of numbers with many digits, these may be separated into suitable groups, preferably of three, counting from the decimal sign towards the left and the right; the groups should be separated by a small space but never by a comma, a point or by other means.

3.3.2 Decimal sign

The preferred decimal sign is a comma on the line. If a dot is used, it shall be on the line.

If the magnitude of the number is less than unity, the decimal sign should be preceded by a zero.

NOTE — In accordance with an ISO Council decision, the decimal sign is a comma in ISO documents.

3.3.3 Multiplication of numbers

The sign for multiplication of numbers is a cross (×) or a dot half-high.

NOTES

1 If a dot half-high is used as the multiplication sign, a comma should be used as the decimal sign. If a dot is used as the decimal sign, a cross should be used as the multiplication sign.

2 In ISO documents, the dot is not used directly between numbers to indicate multiplication.

3.4 Symbols for chemical elements and nuclides

Symbols for chemical elements should be written in roman (upright) type (irrespective of the type used in the rest of the text). The symbol is not followed by a full stop except for normal punctuation, e.g. at the end of a sentence.

Examples : H He C Ca

A complete list of the symbols for the chemical elements is given in ISO 31, part 8, annex A and in ISO 31, part 9, annex A.

The attached subscripts or superscripts specifying a nuclide or molecule should have the following meanings and positions :

The nucleon number (mass number) of a nuclide is shown in the left superscript position, e.g.

^{14}N

The number of atoms of a nuclide in a molecule is shown in the right subscript position, e.g.

$^{14}\text{N}_2$

The proton number may be indicated in the left subscript position, e.g.

$_{64}\text{Gd}$

If necessary, a state of ionization or an excited state may be indicated in the right superscript position.

Examples :

state of ionization : Na^+ PO_4^{3-}
electronic excited state : He^*, NO^*
nuclear excited state : $^{110}\text{Ag}^*$, $^{110}\text{Ag}^m$

3.5 Mathematical signs and symbols

Mathematical signs and symbols recommended for use in the physical sciences and technology are given in ISO 31, part 11.

3.6 Greek alphabet (upright and sloping types)

alpha	A	α	*A*	*α*	nu	N	ν	*N*	*ν*
beta	B	β	*B*	*β*	xi	Ξ	ξ	*Ξ*	*ξ*
gamma	Γ	γ	*Γ*	*γ*	omicron	O	o	*O*	*o*
delta	Δ	δ	*Δ*	*δ*	pi	Π	π, ϖ	*Π*	*π*, *ϖ*
epsilon	E	ε, ϵ	*E*	*ε*, *ϵ*	rho	P	ρ	*P*	*ϱ*
zeta	Z	ζ	*Z*	*ζ*	sigma	Σ	σ	*Σ*	*σ*
eta	H	η	*H*	*η*	tau	T	τ	*T*	*τ*
theta	Θ	ϑ, θ	*Θ*	*ϑ*, *θ*	upsilon	Υ	υ	*Υ*	*υ*
iota	I	ι	*I*	*ι*	phi	Φ	φ, ϕ	*Φ*	*φ*, *ϕ*
kappa	K	κ, ϰ	*K*	*κ*, *ϰ*	chi	X	χ	*X*	*χ*
lambda	Λ	λ	*Λ*	*λ*	psi	Ψ	ψ	*Ψ*	*ψ*
mu	M	μ	*M*	*μ*	omega	Ω	ω	*Ω*	*ω*

Annex A[1]

Guide for terms used in names for physical quantities

A.0 Introduction

If no specific name for a physical quantity exists, a name is commonly formed in combination with terms like coefficient, factor, parameter, ratio, constant, etc. Similarly, terms like specific, density, molar, etc., are added to names of physical quantities to indicate other related or derived quantities. Just as in the choice of an appropriate symbol, the naming of a physical quantity may also need some guidance.

It is not the intention of this guide to impose strict rules or to eliminate the relatively frequent deviations, which have been incorporated in the various scientific languages.

It seems useful, however, to have some guidelines for the usage of these terms. It is possible in this way to give, by the name chosen for a particular quantity, more information about the nature of that quantity. It is hoped that these guidelines will be followed when new names of quantities are introduced, and that, in forming new terms and in reviewing old ones, deviations from these guidelines will be critically examined.

NOTE — The examples in this annex are drawn from existing practice and are not intended to constitute recommendations.

A.1 Coefficients, factors

If, under certain conditions, a quantity A is proportional to a quantity B, this can be expressed by the multiplicative relation $A = k \cdot B$. The quantity k, which occurs as a multiplier in this equation, is often called a coefficient or a factor.

A.1.1 The name *coefficient* should be used when the two quantities A and B have different dimensions.

Examples : Hall coefficient : A_H $\quad \vec{E}_H = A_H |\vec{B} \times \vec{J}|$

linear expansion coefficient : α_l $\quad \mathrm{d}l/l = \alpha_l \mathrm{d}T$

diffusion coefficient : D $\quad \vec{J} = -D \operatorname{grad} n$

Remark : Sometimes the name *modulus* is used instead of the name coefficient. In elasticity, the ratio of stress to strain is called the modulus of elasticity.

Example : Young's modulus : E $\quad E = \sigma/\epsilon$

A.1.2 The name *factor* should be used when the two quantities have the same dimension. A factor is therefore a dimensionless multiplier.

Examples : coupling factor : k $\quad L_{12} = k\sqrt{L_1 L_2}$

quality factor : Q $\quad |X| = Q\,R$

friction factor : μ $\quad F = \mu F_n$

A.2 Parameters, numbers, ratios

A.2.1 Combinations of physical quantities, which occur as such in equations are often considered to constitute new quantities. Such quantities are sometimes called *parameters*.

Example : Grüneisen parameter : γ $\quad \gamma = \alpha_V / \kappa c_V \varrho$

A.2.2 Some dimensionless combinations of physical quantities, such as those occurring in the description of transport phenomena, are called *dimensionless parameters* and carry the word *number* in their names.

Examples : Reynolds number : Re $\quad Re = \varrho v l/\eta$

Prandtl number : Pr $\quad Pr = \eta c_p/\lambda$

(1) Annex A is not an integral part of this standard.

A.2.3 Dimensionless quotients of two quantities, which occur as such in equations, are often called *ratios*.

Examples : heat capacity ratio : γ $\gamma = C_p/C_V$
thermal diffusion ratio : k_T $k_T = D_T/D$
mobility ratio : b $b = \mu_-/\mu_+$

Remark 1 : Sometimes the name *fraction* is used for ratios smaller than one.

Examples : mole fraction : x_B $x_B = n_B/\Sigma n_A$
packing fraction : f $f = \Delta_r/A$

Remark 2 : The term *index* is sometimes used instead of ratio. Extension of this usage is not recommended.

Example : refractive index : n $n = c_0/c$

A.3 Constants

A.3.1 A physical quantity which has the same value under all circumstances is called a *universal constant*. Its name — in so far as no special name exists — includes explicitly the term "constant".

Examples : gravitational constant : G
Planck constant : h

A.3.2 A physical quantity which has for a particular substance the same value under all circumstances, is called a *constant of matter*. Again — in so far as no special name exists — the name of such a quantity includes the term "constant".

Example : decay constant for a particular nuclide : λ

A.3.3 Also other physical quantities, which keep the same value only under particular circumstances, or which result from mathematical calculations, are sometimes given names including the term "constant". Extension of this usage is not recommended.

Examples : equilibrium constant for a chemical reaction (which varies with temperature) : K_ρ
Madelung constant for a particular lattice : α

A.4 Terms with general application

A.4.1 The adjective *specific* is generally added to the name of a quantity to indicate the quotient of that quantity by a mass.

Examples : specific heat capacity $c = C/m$
specific volume $v = V/m$
specific entropy $s = S/m$
specific activity $a = A/m$

A.4.2 The term *density* is often added to the name of a quantity to indicate the quotient of that quantity by a volume (see also A.4.4).

Examples : mass density[1] $\varrho = m/V$
charge density $\varrho = Q/V$
energy density $w = W/V$
number density $n = N/V$

(1) In these cases, the term mass is often omitted.

A.4.3 The term *linear density* is often added to the name of a quantity to indicate the quotient of that quantity by a length.

Examples : linear mass density[1] $\varrho_l = m/l$
linear current density $A = I/b$

Remark : The term *linear* is also often added to the name of a quantity solely to distinguish between similar quantities.

Examples : mean linear range R
mean mass range $R_\varrho = R\varrho$

linear expansion coefficient $\alpha_l = l^{-1}\mathrm{d}l/\mathrm{d}T$
cubic expansion coefficient $\alpha_V = V^{-1}\mathrm{d}V/\mathrm{d}T$

linear attenuation coefficient $\mu = -J^{-1}\mathrm{d}J/\mathrm{d}x$
mass attenuation coefficient $\mu_m = \mu/\varrho$

A.4.4 The term *surface density* is often added to the name of a quantity to indicate the quotient of a scalar quantity by an area.

Examples : surface mass density[1] $\varrho_A = m/A$
surface charge density $\sigma = Q/A$

The term *density* is often added to the name of a quantity expressing a flux (or current) to indicate the quotient of such a quantity by a surface (see also A.4.2).

Examples : density of heat flow rate $q = \Phi/A$
electric current density $J = I/A$
magnetic flux density $B = \Phi/A$

A.4.5 The term *molar* is generally added to the name of a quantity to indicate the quotient of that quantity by an amount of substance.

Examples : molar volume $V_m = V/n$
molar internal energy $U_m = U/n$
molar mass $M = m/n$

A.4.6 The term *concentration* is often added to the name of a quantity, especially for a substance in a mixture, to indicate the quotient of that quantity by the total volume.

Examples : amount-of-substance concentration of substance B[2] $c_B = n_B/V$
molecular concentration of substance B $C_B = N_B/V$
mass concentration of substance B $\varrho_B = m_B/V$

The term *spectral concentration* is used to denote a spectral distribution function (see ISO 31, part 6, Introduction, Special remarks).

(1) In these cases, the term mass is often omitted.

(2) In this case, the term amount-of-substance is often omitted.

Annex B[1]

Guide for the rounding of numbers

B.0 Rounding means replacing the magnitude of a given number by another number called the rounded number, selected from the sequence of integral multiples of a chosen rounding interval.

Examples :

1 rounding interval : 0,1
integral multiples : 12,1, 12,2, 12,3, 12,4, etc.

2 rounding interval : 10
integral multiples : 1 210, 1 220, 1 230, 1 240, etc.

B.1 If there is only one integral multiple nearest the given number, then that is accepted as the rounded number.

Examples :

1 rounding interval : 0,1

given number	rounded number
12,223	12,2
12,251	12,3
12,275	12,3

2 rounding interval : 10

given number	rounded number
1 222,3	1 220
1 225,1	1 230
1 227,5	1 230

B.2 If there are two successive integral multiples equally near the given number, two different rules are in use.

RULE A : The even integral multiple is selected as the rounded number.

Examples :

1 rounding interval : 0,1

given number	rounded number
12,25	12,2
12,35	12,4

2 rounding interval : 10

given number	rounded number
1 225,0	1 220
1 235,0	1 240

RULE B : The higher integral multiple is selected as the rounded number.

(1) Annex B is not an integral part of this standard.

Examples :

1 rounding interval : 0,1

given number	rounded number
12,25	12,3
12,35	12,4

2 rounding interval : 10

given number	rounded number
1 225,0	1 230
1 235,0	1 240

NOTE — Rule A is generally preferable and of special advantage when treating, for example, series of measurements in such a way that the rounding errors are minimized.

Rule B is widely used in computers.

B.3 Rounding in more than one stage by the application of the rules given above may lead to errors; it is therefore recommended always to round in one step.

Example : 12,251 should be rounded to 12,3 and not first to 12,25 and then to 12,2.

B.4 The rules given above should be used only if no special criteria for the selection of the rounded number have to be taken into account. In cases where safety requirements or given limits have to be respected, it may for instance be advisable always to round in one direction.

Quantities and units of space and time

INTRODUCTION

This document, containing a table of *quantities and units of space and time*, is part I of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General introduction — General principles concerning quantities, units and symbols.*

Part I : *Quantities and units of space and time.*

Part II : *Quantities and units of periodic and related phenomena.*

Part III : *Quantities and units of mechanics.*

Part IV : *Quantities and units of heat.*

Part V : *Quantities and units of electricity and magnetism.*

Part VI : *Quantities and units of light and related electromagnetic radiations.*

Part VII : *Quantities and units of acoustics.*

Part VIII : *Quantities and units of physical chemistry and molecular physics.*

Part IX : *Quantities and units of atomic and nuclear physics.*

Part X : *Quantities and units of nuclear reactions and ionizing radiations.*

Part XI : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also part 0.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicitly mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

1) When two types of sloping letters exist (for example as with ϑ, θ; φ, ϕ; g, g) only one of these is given. This does not mean that the other is not equally acceptable.

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. The annexes are not integral parts of the standard. They are arranged in three groups :

a) *Units of the CGS-system with special names*

It is generally preferable not to use CGS-units with special names and symbols together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The Conférence générale des poids et mesures (CGPM : General Conference for Weights and Measures) has classified the SI units, radian and steradian, as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether angle and solid angle are to be considered as base quantities or derived quantities.

In ISO 31, plane angle and solid angle are treated as derived quantities (see also part 0). They are defined in ISO 31 as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[1]

All numbers in the column "Definition" are exact.

In the column "Conversion factors" the conversion factors on which the calculation of others are based are normally given to seven significant digits. When they are exact and contain seven or fewer digits and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

1) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

1. Space and Time

Quantities
1-1.1 . . . 1-3.7

Item No.	Quantity	Symbol	Definition	Remarks
1-1.1	angle (plane angle)	$\alpha, \beta, \gamma, \vartheta, \varphi$, etc.	The angle between two half-lines terminating at the same point is defined as the ratio of the arc cut out on a circle (with its centre at that point) to the radius of the circle	According to this definition, angle is a dimensionless quantity; however, also see the introduction
1-2.1	solid angle	Ω	The solid angle of a cone is defined as the ratio of the area cut out on a spherical surface (with its centre at the apex of that cone) to the square of the radius of the sphere	According to this definition, solid angle is a dimensionless quantity; however, also see the introduction
1-3.1	length	l, (L)		
1-3.2	breadth	b		
1-3.3	height	h		
1-3.4	thickness	d, δ		
1-3.5	radius	r		
1-3.6	diameter	d, D		
1-3.7	length of path	s		

1. Space and Time

Units
1-1.a . . . 1-3.c

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
1-1.a	radian	rad	1 rad is the angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius		See the introduction
1-1.b	degree	°	$1^\circ = \frac{\pi}{180}$ rad	$1^\circ = 0{,}017\,453\,3$ rad	The degree should preferably be subdivided decimally. The unit symbol shall then be placed after the figures *Example* : 15,27°
1-1.c	minute	′	$1' = \frac{1}{60}{}^\circ$		
1-1.d	second	″	$1'' = \frac{1}{60}{}'$		
1-2.a	steradian	sr	1 sr is the solid angle which, having its vertex in the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere		See the introduction
1-3.a	metre	m	The metre is the length equal to 1 650 763,73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom		
1-3.b	ångström	Å	$1\ Å = 10^{-10}$ m	$1\ Å = 10^{-10}$ m (exactly) = 0,1 nm	
1-3.c	nautical mile : n mile		1 n mile = 1 852 m	1 n mile = 1 852 m (exactly)	This definition was adopted by the International Hydrographic Conference, in 1929

1. Space and Time (continued)

Quantities 1-4.1 . . . 1-5.1

Item No.	Quantity	Symbol	Definition	Remarks
1-4.1	area	A, (S)		For an element of area $d\sigma$ is sometimes used
1-5.1	volume	V		For an element of volume $d\tau$ is sometimes used

1. Space and Time (continued)

Units 1-3.d . . . 1-5.b

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
1-3.d	astronomical unit : AU		The astronomical unit of distance is the length of the radius of the unperturbed circular orbit of a body of negligible mass moving round the sun with a sidereal angular velocity of 0,017 202 098 950 radian per day of 86 400 ephemerical seconds	1AU = 1,495 978 70 x 10^{11} m	In the system of astronomical constants of the International Astronomical Union the value adopted for it is : 1 AU = 149 600 x 10^{6} m
1-3.e	parsec	pc	1 pc is the distance at which 1 astronomical unit subtends an angle of 1 second of arc	1 pc = 206 265 AU = 3,085 7 x 10^{16} m	
1-4.a	square metre	m^2	1 m^2 is the area of a square with sides of length 1 m		
1-4.b	are	a	1 a is the area of a square with sides of length 10 m	1 a = 100 m^2 (exactly)	
1-4.c	hectare	ha	1 ha is the area of a square with sides of length 100 m	1 ha = 10^4 m^2 (exactly) = 100 a	
1-5.a	cubic metre	m^3	1 m^3 is the volume of a cube with edges of length 1 m		
1-5.b	litre	l	1 l = 1 dm^3	1 l = 10^{-3} m^3 (exactly)	In 1964 the Conférence générale des poids et mesures redefined the litre as 1 l = 1 dm^3 According to the old definition the litre was equal to 1,000 028 dm^3

1. Space and Time (continued)

Quantities
1-6.1 . . . 1-9.1

Item No.	Quantity	Symbol	Definition	Remarks
1-6.1	time, time interval, duration	t		
1-7.1 (1-8.1)	angular velocity	ω	$\omega = \frac{d\varphi}{dt}$	
1-8.1 (1-9.1)	angular acceleration	α	$\alpha = \frac{d\omega}{dt}$	This equation applies to rotation about a fixed axis. It may also be applied generally, provided that both ω and α are regarded as vectors
1-9.1 (1-10.1)	velocity	u, v, w, c	$v = \frac{ds}{dt}$	When vector notation is not used, the notation u, v, w for the components of a velocity c is recommended. Further, c or c_0 is used for speed of propagation of light in vacuo

1. Space and Time (continued)

Units
1-6.a . . . 1-9.c

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
1-6.a	second	s	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom		
1-6.b	minute	min	1 min = 60 s		For representations of time of day, see ISO 3307-1975
1-6.c	hour	h	1 h = 60 min	1 h = 3 600 s	
1-6.d	day	d	1 d = 24 h	1 d = 86 400 s	
1-7.a	radian per second	rad/s			For other units, see 1-1.b . . . d
1-8.a	radian per second squared	rad/s²			For other units, see 1-1.b . . . d
1-9.a	metre per second	m/s			
1-9.b	kilometre per hour	km/h		1 km/h = $\frac{1}{3,6}$ m/s = 0,277 778 m/s	
1-9.c	knot : kn		1 kn = 1 n mile per hour	1 kn = 0,514 444 m/s	

1. Space and Time (concluded)

Quantities
1-10.1 . . . 1-10.2

Item No.	Quantity	Symbol	Definition	Remarks
1-10.1 (1-11.1)	acceleration	a	$a = \frac{dv}{dt}$	
1-10.2 (1-11.2)	acceleration of free fall, acceleration due to gravity	g		Standard acceleration of free fall : $g_n = 9{,}806\ 65\ m/s^2$ (Conférence générale des poids et mesures, 1901)

1. Space and Time (concluded)

Units
1-10.a . . . 1-10.b

Item No.	Name of unit and in certain cases abbreviation for this name	International symbol for unit	Definition	Conversion factors	Remarks
1-10.a	metre per second squared	m/s^2			
1-10.b	gal	Gal	1 Gal = 1 cm/s^2	1 Gal = 0,01 m/s^2	The gal is used only for the quantity g; in particular, the milligal is commonly used in geodesy

ANNEX A

UNITS BASED ON THE FOOT, POUND AND SECOND AND SOME OTHER UNITS

Quantity item No.	Quantity	Unit Item No.	Name of unit with symbol	Definition and conversion factors
1-3.1	length	1-3.A.a	inch : in	1 in = 25,4 mm (exactly) The expression "mil" or "thou" are sometimes used to denote the "milli-inch"
		1-3.A.b	foot : ft	1 ft = 12 in 1 ft = 0,304 8 m (exactly) The U.S. Survey foot, used by the U.S. Coast and Geodetic Survey, is defined as 1 U.S. Survey foot = $\frac{1\,200}{3\,937}$ m = 1,000 002 x 0,304 8 m
		1-3.A.c	yard : yd	1 yd = 3 ft = 36 in = 0,914 4 m (exactly) This definition was adopted legally by the United States in 1959 (Announcement U.S. Dep. of Commerce, Nat. Bur. Standard, F.R. Doc. 59-5442 d.d. June 30, 1959) and by the United Kingdom in 1963 (Weights and Measures Act, 1963). An exception is made for the U.S. Survey foot – see the remark to 1-3.A.b.
		1-3.A.d	mile	1 mile = 5 280 ft 1 mile = 1 609,344 m (exactly) The mile of 5 280 ft is also known as a statute mile
1-4.1	area	1-4.A.a	square inch : in^2	1 in^2 = 6,451 6 cm^2 (exactly) The expression "circular mil" is sometimes used to designate an area of $\frac{\pi}{4} \times 10^{-6}$ in^2
		1-4.A.b	square foot : ft^2	1 ft^2 = 0,092 903 06 m^2 (exactly)
		1-4.A.c	square yard : yd^2	1 yd^2 = 0,836 127 m^2 The abbreviations sq in, sq ft and sq yd are commonly used
		1-4.A.d	square mile : $mile^2$	1 $mile^2$ = 2,589 988 km^2 1 $mile^2$ (U.S. Survey) = 2,589 998 km^2 1 $mile^2$ = 640 acres (exactly)
		1-4.A.e	acre	1 acre = 4 046,856 m^2 1 acre (U.S. Survey) = 4 046,873 m^2 1 acre = 4 840 yd^2 (exactly)

ANNEX A (*concluded*)

UNITS BASED ON THE FOOT, POUND AND SECOND AND SOME OTHER UNITS

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
1-5.1	volume	1-5.A.a	cubic inch : in^3	1 in^3 = 16,387 064 cm^3 (exactly)
		1-5.A.b	cubic foot : ft^3	1 ft^3 = 28,316 8 dm^3
		1-5.A.c	cubic yard : yd^3	1 yd^3 = 0,764 555 m^3 The abbreviations cu in, cu ft and cu yd are commonly used
		1-5.A.d	gallon (UK) : gal (UK)	1 gal (UK) = 277,420 in^3; 1 gal (UK) = 4,546 09 dm^3 = 1,200 95 gal (US)
		1-5.A.e	pint (UK) : pt (UK)	8 pt (UK) = 1 gal (UK); 1 pt (UK) = 0,568 262 dm^3 = 1,200 95 liq pt (US)
		1-5.A.f	fluid ounce (UK) : fl oz (UK)	160 fl oz (UK) = 1 gal (UK); 1 fl oz (UK) = 28,413 1 cm^3 = 0,960 760 fl oz (US)
		1-5.A.g	bushel (UK)	1 bushel (UK) = 8 gal (UK); 1 bushel (UK) = 36,368 7 dm^3 = 1,032 06 bu (US)
		1-5.A.h	gallon (US) : gal (US)	1 gal (US) = 231 in^3; 1 gal (US) = 3,785 41 dm^3 = 0,832 674 gal (UK)
		1-5.A.i	liquid pint (US) : liq pt (US)	8 liq pt (US) = 1 gal (US); 1 liq pt (US) = 0,473 176 dm^3 = 0,832 674 pt (UK)
		1-5.A.j	fluid ounce (US) : fl oz (US)	128 fl oz (US) = 1 gal (US); 1 fl oz (US) = 29,573 5 cm^3 = 1,040 84 fl oz (UK)
		1-5.A.k	barrel (US) for petroleum, etc. (petroleum)	1 barrel (US) = 9 702 in^3; 1 barrel (US) = 158,987 dm^3 (petroleum) = 34,972 3 gal (UK) = 42 gal (US)
		1-5.A.l	bushel (US) : bu (US)	1 bu (US) = 2 150,42 in^3; 1 bu (US) = 35,239 1 dm^3 = 0,968 939 bushel (UK)
		1-5.A.m	dry pint (US) : dry pt (US)	64 dry pt (US) = 1 bu (US); 1 dry pt (US) = 0,550 610 dm^3 = 0,968 939 pt (UK)
		1-5.A.n	dry barrel (US) : bbl (US)	1 bbl (US) = 7 056 in^3; 1 bbl (US) = 115,627 dm^3 (dry) (dry)
1-9.1	velocity	1-9.A.a	foot per second : ft/s	1 ft/s = 0,304 8 m/s (exactly)
		1-9.A.b	mile per hour : mile/h	1 mile/h = 0,447 04 m/s (exactly)
1-10.1	acceleration	1-10.A.a	foot per second squared : ft/s^2	1 ft/s^2 = 0,304 8 m/s^2 (exactly)

ANNEX B

OTHER NON-SI UNITS GIVEN FOR INFORMATION, ESPECIALLY REGARDING THE CONVERSION FACTOR

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
1-1.1	angle (plane angle)	1-1.B.a	grade, gon : ^{g}, gon	$1^g = 1\ \text{gon} = \frac{\pi}{200}\ \text{rad}$ $1^g = 0{,}015\ 708\ 0\ \text{rad}$
1-3.1	length	1-3.B.a	light year : (l.y.)[1]	1 light year is the distance traversed in 1 year by electromagnetic waves in free space 1 l.y. = 9,460 53 × 10^{15} m
1-6.1	time	1-6.B.a	year, tropical year : a, a_{trop}	The tropical year is the time elapsing between two successive passages of the sun through the mean vernal equinox This time interval is related to the corresponding difference of mean longitude of the sun, which depends on time in a not exactly linear form; i.e. a_{trop} is not constant but decreases at a rate of nearly 0,53 s per century. The tropical year is approximately equal to 365,242 20 d = 31 556 926 s

1) "l.y." is an abbreviation for the name light year.

Quantities and units of periodic and related phenomena

INTRODUCTION

This document, containing a table of *quantities and units of periodic and related phenomena*, is part II of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General introduction – General principles concerning quantities, units and symbols.*

Part I : *Quantities and units of space and time.*

Part II : *Quantities and units of periodic and related phenomena.*

Part III : *Quantities and units of mechanics.*

Part IV : *Quantities and units of heat.*

Part V : *Quantities and units of electricity and magnetism.*

Part VI : *Quantities and units of light and related electromagnetic radiations.*

Part VII : *Quantities and units of acoustics.*

Part VIII : *Quantities and units of physical chemistry and molecular physics.*

Part IX : *Quantities and units of atomic and nuclear physics.*

Part X : *Quantities and units of nuclear reactions and ionizing radiations.*

Part XI : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also part 0.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicitly mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

1) When two types of sloping letters exist (for example as with ϑ, θ; φ, ϕ; and g, g) only one of these is given. This does not mean that the other is not equally acceptable.

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. The annexes are not integral parts of the standard. They are arranged in three groups :

a) *Units of the CGS-system with special names*

It is generally preferable not to use CGS-units with special names and symbols together with SI units.

b) *Units based on the foot, pound and second and some other unit*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The Conférence générale des poids et mesures (CGPM : General Conference for Weights and Measures) has classified the SI units, radian and steradian, as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether angle and solid angle are to be considered as base quantities or derived quantities.

In ISO 31, plane angle and solid angle are treated as derived quantities (see also part 0). They are defined in ISO 31 as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[1)]

All numbers in the column "Definition" are exact.

In the column "Conversion factors" the conversion factors on which the calculation of others are based are normally given to seven significant digits. When they are exact and contain seven or fewer digits and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

SPECIAL REMARKS

Remark on level difference

In ISO 31, level difference is defined as the natural logarithm of the ratio of two quantities of the same kind. It is a dimensionless quantity. Although the coherent unit corresponding to this definition is the number 1, it is convenient in practice to use the special name neper.

The expression for level difference in terms of Briggsian logarithms follows from the definition.

The relation between the neper and the decibel, the units commonly used for expressing level difference, is

$$1\ \mathrm{dB} = \frac{\ln 10}{20}\ \mathrm{Np}$$

The relation between the bel and decibel is $1\ \mathrm{dB} = 10^{-1}\ \mathrm{B}$, but only the decibel is given in ISO 31 since the bel is not often used.

1) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

Periodic and related phenomena

2. Periodic and related phenomena

Quantities
2-1.1 . . . 2-6.2

Item No.	Quantity	Symbol	Definition	Remarks
2-1.1	period, periodic time	T	Time of one cycle	
2-2.1	time constant of an exponentially varying quantity	τ, (T)	Time after which the quantity would reach its limit if it maintained its initial rate of variation	If a quantity is a function of time given by $F(t) = A + Be^{-t/\tau}$ then τ is the time constant
2-3.1	frequency	f, ν	$f = 1/T$	
2.3.2	rotational frequency	n	Number of revolutions divided by time	
2-4.1	angular frequency, circular frequency, pulsatance	ω	$\omega = 2\pi f$	
2-5.1	wavelength	λ		
2-6.1	wavenumber	σ	$\sigma = 1/\lambda$	The vector quantities corresponding to wavenumber and circular wavenumber are called wavevector and propagation vector respectively.
2-6.2	circular wavenumber	k	$k = 2\pi\sigma$	

2. Periodic and related phenomena

Units
2-1.a . . . 2-6.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
2-1.a	second	s			
2-2.a	second	s			
2-3.a	hertz	Hz	1 Hz is the frequency of a periodic phenomenon of which the period is 1 s		
2-3.b	reciprocal second, second to the power minus one	s^{-1}	1 Hz = 1 s^{-1}		The designations "revolutions per minute" (r/min) and "revolutions per second" (r/s) are widely used for rotational frequency in specifications on rotating machinery[1]
2-4 a	radian per second	rad/s			See the Introduction
2-4 b	reciprocal second, second to the power minus one	s^{-1}			
2-5 a	metre	m			
2-5.b	ångström	Å	1 Å = 10^{-10} m	1 Å = 10^{-10} m (exactly) = 0,1 nm	
2-6 a	reciprocal metre, metre to the power minus one	m^{-1}			

1) See also IEC Publication 27-1 (1971)

Quantities
2-7.1 . . . 2-11.3

2. Periodic and related phenomena (concluded)

Item No.	Quantity	Symbol	Definition	Remarks
2-7.1	amplitude level difference, field level difference	L_F	$L_F = \ln (F_1/F_2)$ where F_1 and F_2 represent two amplitudes of the same kind	These quantities are dimensionless. If $P_1/P_2 = (F_1/F_2)^2$ then $L_P = L_F$ Similar names, symbols and definitions apply to level differences based on other quantities which are linear or quadratic functions of the amplitudes, respectively. The quantity on which the level difference is based should be specified in the name and the subscript of the symbol, e.g. field strength level difference L_E. A level difference from a standard situation is described simply as "level"
	power level difference	L_P	$L_P = \frac{1}{2}\ln(P_1/P_2)$ where P_1 and P_2 represent two powers	
2-9.1	damping coefficient	δ	If a quantity is a function of time given by $F(t) = Ae^{-\delta t}\sin[\omega(t-t_0)]$ then δ is the damping coefficient	$\tau = 1/\delta$ is the time constant (relaxation time) of the amplitude. The quantity $\omega(t-t_0)$ is called the phase
2-10.1	logarithmic decrement	Λ	Product of damping coefficient and period.	This quantity is dimensionless
2-11.1	attenuation coefficient	α	If a quantity is a function of distance x given by $F(x) = Ae^{-\alpha x}\cos[\beta(x-x_0)]$ then α is the attenuation coefficient and β is the phase coefficient $\gamma = \alpha + j\beta$	The quantity $l = 1/\alpha$ is called the attenuation length. The quantity $\beta(x-x_0)$ is called the phase
2-11.2	phase coefficient	β		
2-11.3	propagation coefficient	γ		

2. Periodic and related phenomena (concluded)

Units
2-7.a . . . 2-11.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
2-7.a	neper	Np	1 Np is the amplitude level difference when $\ln(F_1/F_2) = 1$		See the Introduction, special remarks
2-7.b	decibel	dB	1 dB is the amplitude level difference when $20 \lg (F_1/F_2) = 1$	$1\ \text{dB} = \frac{\ln 10}{20}\ \text{Np} = 0{,}115\,129\ \text{Np}$	The numerical value of L_F expressed in decibels is given by $20\lg(F_1/F_2)$ and the numerical value of L_P expressed in decibels is given by $10\lg(P_1/P_2)$
2-8.a	neper	Np	1 Np is the power level difference when $\frac{1}{2}\ln(P_1/P_2) = 1$		
2-8.b	decibel	dB	1 dB is the power level difference when $10 \lg (P_1/P_2) = 1$	$1\ \text{dB} = \frac{\ln 10}{20}\ \text{Np} = 0{,}115\,129\ \text{Np}$	
2-9.a	reciprocal second, second to the power minus one	s^{-1}			
2-9.b	neper per second	Np/s			See the Introduction, special remarks
2-10.a	neper	Np			See the Introduction, special remarks
2-11.a	reciprocal metre, metre to the power minus one	m^{-1}			

Quantities and units of mechanics

INTRODUCTION

This document, containing a table of *quantities and units of mechanics*, is part III of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

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Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

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In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing.

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Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also part 0.

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2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

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c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The Conférence générale des poids et mesures (CGPM : General Conference for Weights and Measures) has classified the SI units, radian and steradian, as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether angle and solid angle are to be considered as base quantities or derived quantities.

In ISO 31, plane angle and solid angle are treated as derived quantities (see also part 0). They are defined in ISO 31 as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[1]

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others are based are normally given to seven significant digits. When they are exact and contain seven or fewer digits and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

1) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

3. Mechanics

Quantities
3-1.1 . . . 3-8.1

Item No.	Quantity	Symbol	Definition	Remarks
3-1.1	mass	m		
3-2.1	density (mass density)	ϱ	Mass divided by volume	
3-3.1	relative density	d	Ratio of the density of a substance to the density of a reference substance under conditions that should be specified for both substances	This quantity is dimensionless
3-4.1	specific volume	v	Volume divided by mass	
3-5.1 —	linear density	ϱ_l	Mass divided by length	
3-6.1 —	surface density	ϱ_A, (ϱ_S)	Mass divided by area	
3-7.1 (3-5.1)	momentum	p	Product of mass and velocity	
3-8.1 (3-6.1)	moment of momentum, angular momentum	L	The moment of momentum of a particle about a point is equal to the vector product of the radius vector from this point to the particle and the momentum of the particle	

3. Mechanics

Units
3-1.a . . . 3-8.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
3-1.a	kilogram	kg	The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram		1st CGPM (1889) and 3rd CGPM (1901) NOTE – Names of decimal multiples and sub-multiples of the unit of mass are formed by attaching prefixes to the word "gram" (CIPM (1967)). $1\ g = 10^{-3}\ kg$
3-1.b	tonne	t	$1\ t = 1\ 000\ kg$		Also called in English metric ton
3-2.a	kilogram per cubic metre	kg/m^3			
3-2.b	tonne per cubic metre	t/m^3		$1\ t/m^3 = 1\ 000\ kg/m^3 = 1\ g/cm^3$	Also called in English metric ton per cubic metre
3-2.c	kilogram per litre	kg/l		$1\ kg/l = 1\ 000\ kg/m^3 = 1\ g/cm^3$	
3-4.a	cubic metre per kilogram	m^3/kg			
3-5.a	kilogram per metre	kg/m			The unit tex is used for textile filaments; $1\ tex = 10^{-6}\ kg/m = 1\ g/km$
3-6.a	kilogram per square metre	kg/m^2			
3-7.a	kilogram metre per second	kg·m/s			
3-8.a	kilogram metre squared per second	$kg \cdot m^2/s$			

Quantities
3-9.1 . . . 3-11.1

3. Mechanics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
3-9.1 (3-7.1)	moment of inertia (dynamic moment of inertia)	I, J	The (dynamic) moment of inertia of a body about an axis is the sum (integral) of the products of its mass-elements and the squares of their distances from the axis	To be distinguished from 3-18.1 and 3-18.2
3-10.1 (3-8.1)	force	F	The resultant force acting on a body is equal to the rate of change of the momentum of the body	
3-10.2 (3-8.2)	weight	$G, (P, W)$	The weight of a body in a specified reference system is that force which, when applied to the body, would give it an acceleration equal to the local acceleration of free fall in that reference system	When the reference system is the earth, the quantity here defined has commonly been called the local force of gravity on the body. It is noteworthy that the "weight" arises not only from the resultant of the gravitational forces existing at the place where the body is, but also from the local centrifugal force The effect of atmospheric buoyancy is excluded, and consequently the weight defined is the weight in vacuo. (See also Comptes Rendus, 3eme Conférence Générale des Poids et Mesures, 1901, p. 70) In common parlance, the word "weight" is often used to mean mass
3-11.1 —	gravitational constant	$G, (f)$	The gravitational force between two particles is $F = G\frac{m_1 m_2}{r^2}$ where r is the distance between the particles, and m_1 and m_2 are their masses	$G = (6,672\,0 \pm 0,004\,1)\ 10^{-11}$ $N{\cdot}m^2/kg^2$ *

* CODATA Bulletin 11 (1973).

3. Mechanics (continued)

Units
3-9.a . . . 3-11.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
3-9.a	kilogram metresquared	$kg{\cdot}m^2$			
3-10.a	newton	N	1 N is that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/s^2		
3-11.a	newton square metre per kilogram squared	$N{\cdot}m^2/kg^2$			

Quantities
3-12.1 . . . 3-13.3

3. Mechanics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
3-12.1 (3-10.1)	moment of force	M	The moment of a force about a point is equal to the vector product of the radius vector, from this point to any point on the line of action of the force, and the force	In elasticity, M is used for bending moment and T for twisting or torsional moment
3-12.2 (3-10.3)	torque, moment of a couple	T		
3-13.1 (3-11.1)	pressure	p	Force divided by area	The symbol p_e is recommended for gauge pressure, defined as $p - p_{amb}$, where p_{amb} is the ambient pressure. The numerical value of a gauge pressure is positive or negative according as p is larger or smaller than p_{amb} respectively
3-13.2 (3-11.2)	normal stress	σ		
3-13.3 (3-11.3)	shear stress	τ		

3. Mechanics (continued)

Units
3-12.a . . . 3-13.c

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
3-12.a	newton metre	N·m			The symbol for this unit should be written in such a way that it could not be confused with the symbol for millinewton
3-13.a	pascal	Pa	1 Pa = 1 N/m²		
3-13.b	bar	bar	1 bar = 10^5 Pa	1 bar = 10^5 Pa (exactly)	1 bar = 100 kPa = 0,1 MPa The use of the bar should be restricted to the field of fluid pressure.
3-13.c	standard atmosphere	atm	1 atm = 101 325 Pa	1 atm = 101 325 Pa (exactly)	Definition adopted by the 10th Conférence générale des poids et mesures (1954)

Quantities
3-14.1 . . . 3-17.1

3. Mechanics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
3-14.1 (3-12.1)	linear strain (relative elongation)	e, ε	$\varepsilon = \frac{\Delta l}{l_0}$ where l_0 is length in a reference state to be specified, and Δl is increase in length	These quantities are dimensionless
3-14.2 (3-12.2)	shear strain	γ	$\gamma = \frac{\Delta x}{d}$ where Δx is the parallel displacement of the upper surface with respect to the lower surface of a layer of thickness d	
3-14.3 (3-12.3)	volume strain (bulk strain)	ϑ	$\vartheta = \frac{\Delta V}{V_0}$ where V_0 is volume in a reference state to be specified, and ΔV is increase in volume	
3-15.1 (3-13.1)	Poisson ratio, Poisson number	μ, ν	Lateral contraction divided by elongation	This quantity is dimensionless The quantity defined by Poisson was the reciprocal : $m = \frac{1}{\mu}$
3-16.1 (3-14.1)	modulus of elasticity	E	$E = \sigma/\varepsilon$	E and G are also called Young modulus and Coulomb modulus respectively
3-16.2 (3-14.2)	shear modulus, modulus of rigidity	G	$G = \tau/\gamma$	The strains ε, γ and ϑ in these definitions are those corresponding to the excess stresses σ and τ, and the excess pressure, p
3-16.3 (3-14.3)	bulk modulus, modulus of compression	K	$K = -p/\vartheta$	
3-17.1 (3-15.1)	compressibility, bulk compressibility	κ	$\kappa = -\frac{1}{V}\frac{dV}{dp}$	See also part IV, item 4-5.1

Units
3-16.a . . . 3-17.a

3. Mechanics (continued)

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
3-16.a	pascal	Pa	1 Pa = 1 N/m²		
3-17.a	reciprocal pascal, pascal to the power minus one	Pa^{-1}	$1\ Pa^{-1} = 1\ m^2/N$		

Quantities
3-18.1 . . . 3-22.1

3. Mechanics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
3-18.1 (3-16.1)	second moment of area (second axial moment of area)	I_a, (I)	The second axial moment of area of a plane area (section) about an axis in its plane is the sum (integral) of the products of its elements of area and the squares of their distances from the axis	These quantities should be distinguished from 3-9.1. They have often been given the name "moment of inertia" The symbol I may be used for second moment of area when no danger of confusion exists with moment of inertia (3-9.1)
3-18.2 (3-16.2)	second polar moment of area	I_p	The second polar moment of area of a plane area (section) about a point in its plane is the sum (integral) of the products of its elements of area and the squares of their distances from the point	
3-19.1 (3-17.1)	section modulus	Z, W	The section modulus of a plane area (section) about an axis in its plane is the second moment of area divided by the distance from the axis to the most remote point of the area	
3-20.1 (3-18.1)	coefficient of friction, friction factor	μ, (f)	Ratio of frictional force to normal force, for a sliding body	This quantity is dimensionless
3-21.1 (3-19.1)	viscosity (dynamic viscosity)	η, (μ)	$\tau_{xz} = \eta \frac{dv_x}{dz}$ where τ_{xz} is the shear stress in a fluid moving with a velocity gradient dv_x/dz perpendicular to the plane of shear	This definition applies to laminar flow for which $v_z = 0$
3-22.1 (3-20.1)	kinematic viscosity	ν	$\nu = \eta/\varrho$ where ϱ is the density	

3. Mechanics (continued)

Units
3-18.a . . . 3-22.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
3-18.a	metre to the fourth power	m^4			
3-19.a	metre cubed	m^3			
3-21.a	pascal second	Pa·s	1 Pa·s is the viscosity of a fluid in which the velocity under a shear stress of 1 Pa has a gradient of 1 m/s per metre perpendicular to the plane of shear		1 Pa·s = 1 N·s/m² = 1 kg·m⁻¹·s⁻¹
3-22.a	metre squared per second	m^2/s	1 m^2/s is the kinematic viscosity of a fluid with dynamic viscosity 1 Pa·s and density 1 kg/m^3		

Quantities
3-23.1 . . . 3-27.1

3. Mechanics (concluded)

Item No.	Quantity	Symbol	Definition	Remarks
3-23.1 (3-21.1)	surface tension	γ, σ	Force perpendicular to a line element in a surface divided by the length of the line element	
3-24.1 (3-22.1)	work	$W, (A)$	Force multiplied by displacement in the direction of the force	See also part IV
3-24.2 (3-22.2)	energy	$E, (W)$		
3-24.3 (3-22.3)	potential energy	E_p, V, Φ		
3-24.4 (3-22.4)	kinetic energy	E_k, K, T		
3-25.1 (3-23.1)	power	P	Rate of energy transfer	
3-26.1 —	mass flow rate	q_m	Rate at which mass crosses a surface	
3-27.1 —	volume flow rate	q_V	Rate at which volume crosses a surface	

3. Mechanics (concluded)

Units
3-23.a . . . 3-27.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
3-23.a	newton per metre	N/m			1 N/m = 1 J/m²
3-24.a	joule	J	1 J is the work done when the point of application of a force of 1 N is displaced through a distance of 1 m in the direction of the force		1 J = 1 N·m = 1 W·s
3-24.b	watt hour	W·h	1 W·h is the energy delivered in 1 h by an energy source of 1 W power	1 W·h = 3,6 × 10³ J (exactly) = 3,6 kJ (exactly)	1 kW·h = 3,6 MJ
3-24.c	electronvolt	eV	1 eV is the kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuo	1 eV = 1,602 19 × 10^{-19} J	1 eV = (1,602 189 2 ± 0,000 004 6) × 10^{-19} J *

* CODATA Bulletin 11 (1973).

ANNEX A

UNITS OF THE CGS-SYSTEM WITH SPECIAL NAMES

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
3-10.1	force	3-10.A.a	dyne : dyn	1 dyn is that force which, when applied to a body having a mass of 1 g, gives it an acceleration of 1 cm/s^2. 1 dyn = 10^{-5} N (exactly)
3-21.1	viscosity (dynamic viscosity)	3-21.A.a	poise : P	1 P is the viscosity of a fluid in which the velocity under a shear stress of 1 dyn/cm^2 has a gradient of 1 cm/s per centimetre perpendicular to the plane of shear. 1 P = 1 dyn·s/cm^2 = 1 g·cm^{-1}·s^{-1} = 0,1 Pa·s (exactly)
3-22.1	kinematic viscosity	3-22.A.a	stokes : St	1 St is the kinematic viscosity of a fluid with dynamic viscosity 1 P and density 1 g/cm^3. 1 St = 10^{-4} m^2/s (exactly)
3-23.1	surface tension	3-23.A.a	dyne per centimetre : dyn/cm	1 dyn/cm = 1 erg/cm^2 = 10^{-3} N/m
3-24.1 3-24.2	work energy	3-24.A.a	erg : erg	1 erg is the work done when the point of application of a force of 1 dyn is displaced through a distance of 1 cm in the direction of the force. 1 erg = 1 dyn·cm = 10^{-7} J (exactly)
3-25.1	power	3-25.A.a	erg per second : erg/s	1 erg/s = 10^{-7} W (exactly)

ANNEX B

UNITS BASED ON THE FOOT, POUND AND SECOND AND SOME OTHER UNITS

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
3-1.1	mass	3-1.B.a	pound : lb	1 lb = 0,453 592 37 kg (exactly)
		3-1.B.b	grain : gr	1 gr = $\frac{1}{7\,000}$ lb = 64,798 91 mg (exactly)
		3-1.B.c	ounce : oz	1 oz = $\frac{1}{16}$ lb = 437,5 gr (exactly) = 28,349 5 g
		3-1.B.d	hundredweight : cwt	1 cwt (UK) = 1 long cwt (US) = 112 lb = 50,802 3 kg 1 cwt (US) = 100 lb = 45,359 2 kg
		3-1.B.e	ton	1 ton (UK) = 1 long ton (US) = 2 240 lb = 1 016,05 kg = 1,016 05 t 1 ton (US) = 2 000 lb = 907,185 kg = 0,907 185 t
		3-1.B.f	troy ounce or apothecaries' ounce	1 troy ounce = 480 gr = 31,103 5 g
3-2.1	density (mass density)	3-2.B.a	pound per cubic foot : lb/ft^3	1 lb/ft^3 = 16,018 5 kg/m^3
3-10.1	force	3-10.B.a	pound-force : lbf	1 lbf = 4,448 22 N This unit must be distinguished from the local weight of a body having a mass of 1 lb
3-12.1	moment of force	3-12.B.a	foot pound-force : ft·lbf	1 ft·lbf = 1,355 82 N·m
3-13.1	pressure	3-13.B.a	pound-force per square inch : lbf/in^2	1 lbf/in^2 = 6 894,76 Pa
3-18.1 3-18.2	second moment of area second polar moment of area	3-18.B.a	inch to the fourth power : in^4	1 in^4 = 41,623 1 x 10^{-8} m^4

ANNEX B (*concluded*)

UNITS BASED ON THE FOOT, POUND AND SECOND AND SOME OTHER UNITS

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
3-19.1	section modulus	3-19.B.a	inch cubed : in^3	1 in^3 = 16,387 1 x 10^{-6} m^3
3-22.1	kinematic viscosity	3-22.B.a	square foot per second : ft^2/s	1 ft^2/s = 0,092 903 0 m^2/s
3-24.1 3-24.2	work energy	3-24.B.a	foot pound-force : ft·lbf	1 ft·lbf = 1,355 82 J
3-25.1	power	3-25.B.a	foot pound-force per second : ft·lbf/s	1 ft·lbf/s = 1,355 82 W 1 horsepower (hp) = 550 ft·lbf/s = 745,700 W

ANNEX C

OTHER UNITS GIVEN FOR INFORMATION, ESPECIALLY REGARDING THE CONVERSION FACTOR

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
3-1.1	mass	3-1.C.a	metric carat †	1 metric carat = 200 mg (exactly)
3-10.1	force	3-10.C.a	kilogram-force † : kgf	1 kgf = 9,806 65 N (exactly) The abbreviations kgf (kilogram-force) and kp (kilopond) are both used. This unit must be distinguished from the local weight of a body having a mass of 1 kg
3-12.1	moment of force	3-12.C.a	kilogram-force metre † : kgf·m	1 kgf·m = 9,806 65 N·m (exactly)
3-13.1	pressure	3-13.C.a	kilogram-force per square metre † : kgf/m^2	1 kgf/m^2 = 9,806 65 Pa (exactly)
		3-13.C.b	torr † : Torr	1 Torr = $\frac{1}{760}$ atm = 133,322 Pa
		3-13.C.c	technical atmosphere † : at	1 at = 1 kgf/cm^2 = 0,967 841 atm = 98 066,5 Pa (exactly)
		3-13.C.d	conventional millimetre of water † : mmH_2O	1 mmH_2O = 10^{-4} at = 9,806 65 Pa (exactly)
		3-13.C.e	conventional millimetre of mercury † : mmHg	1 mmHg = 13,595 1 mmH_2O = 133,322 Pa
3-24.1 3-24.2	work energy	3-24.C.a	kilogram-force metre † : kgf·m	1 kgf·m = 9,806 65 J (exactly)
3-25.1	power	3-25.C.a	kilogram-force metre per second † : kgf·m/s	1 kgf·m/s = 9,806 65 W (exactly)
		3-25.C.b	metric horse-power, cheval vapeur †	1 metric horsepower, cheval vapeur = 75 kgf·m/s = 735,499 W

† The use of those units marked with † is deprecated.

Quantities and units of heat

INTRODUCTION

This document, containing a table of *quantities and units of heat*, is part IV of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General introduction — General principles concerning quantities, units and symbols.*

Part I : *Quantities and units of space and time.*

Part II : *Quantities and units of periodic and related phenomena.*

Part III : *Quantities and units of mechanics.*

Part IV : *Quantities and units of heat.*

Part V : *Quantities and units of electricity and magnetism.*

Part VI : *Quantities and units of light and related electromagnetic radiations.*

Part VII : *Quantities and units of acoustics.*

Part VIII : *Quantities and units of physical chemistry and molecular physics.*

Part IX : *Quantities and units of atomic and nuclear physics.*

Part X : *Quantities and units of nuclear reactions and ionizing radiations.*

Part XI : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also part 0.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicitly mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

1) When two types of sloping letters exist (for example as with ϑ, θ; φ, ϕ; and g, g) only one of these is given. This does not mean that the other is not equally acceptable.

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. The annexes are not integral parts of the standards. They are arranged in three groups :

a) *Units of the CGS-system with special names*

It is generally preferable not to use CGS-units with special names and symbols together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The Conférence générale des poids et mesures (CGPM : General Conference for Weights and Measures) has classified the SI units, radian and steradian, as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether angle and solid angle are to be considered as base quantities or derived quantities.

In ISO 31, plane angle and solid angle are treated as derived quantities (see also part 0). They are defined in ISO 31 as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[1]

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others are based are normally given to seven significant digits. When they are exact and contain seven or fewer digits and where it is not obvious from the context, the work "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

1) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

Quantities
4-1.1 . . . 4-2.1

4. Heat

Item No.	Quantity	Symbol	Definition	Remarks
4-1.1	thermodynamic temperature	T, Θ		The thermodynamic temperature is defined according to the principles of thermodynamics
4-2.1	Celsius temperature	t, θ	$t = T - T_0$ where T_0 is fixed by convention to be $T_0 = 273{,}15$ K	The thermodynamic temperature T_0 is by definition 0,01 K below the thermodynamic temperature of the triple point of water

4. Heat

Units
4-1.a . . . 4-2.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
4-1.a	kelvin	K	The kelvin, unit of thermodynamic temperature, is the fraction 1/273,16 of the thermodynamic temperature of the triple point of water		**Temperature interval** The units of thermodynamic and Celsius temperature interval or difference are identical. The Conférence générale des poids et mesures has recommended that such intervals or differences should be expressed in kelvins (K) or in degrees Celsius (°C). Other names and symbols, such as "degré", "deg" or "degree", should be abandoned. **The "I.P.T.S. (1968)"** For the purpose of practical measurements, the Conférence générale des poids et mesures introduced the International Practical Temperature Scale. This temperature scale is based on a number of fixed points and interpolation procedures with the help of certain measuring instruments and defines the temperature down to 13,81 K. The last version, approved in 1976, is an amended edition of the International Practical Temperature Scale 1968. The thermodynamic temperature and Celsius temperature defined by this scale are indicated as T_{68} and t_{68} respectively, where $t_{68} = T_{68} - T_0$ T_{68} and t_{68} are considered to be the best approximations at present to T and t respectively. The units of T_{68} and t_{68} are the kelvin and degree Celsius respectively, as in the case of T and t [for complete text, see : *Metrologia* 12 (1976) No. 1]. The previously accepted "helium scales" deviate too much from the thermodynamic temperature at low temperatures and have therefore been withdrawn.
4-2.a	degree Celsius	°C	Degree Celsius is a special name for the unit kelvin for use in stating values of Celsius temperature		

Quantities
4-3.1 . . . 4-11.1

4. Heat (continued)

Item No.	Quantity	Symbol	Definition	Remarks
4-3.1	linear expansion coefficient	α_l	$\alpha_l = \frac{1}{l}\frac{dl}{dT}$	The subscripts in the symbols may be omitted when no confusion will result The name pressure coefficient and the symbol β are also used for the quantity 4-3.3 The quantities 4-3.1 to 4-5.1 are not completely defined unless the type of change is specified
4-3.2	cubic expansion coefficient	α_V, γ	$\alpha_V = \frac{1}{V}\frac{dV}{dT}$	
4-3.3	relative pressure coefficient	α_p	$\alpha_p = \frac{1}{p}\frac{dp}{dT}$	
4-4.1 (4-3.3)	pressure coefficient	β	$\beta = \frac{dp}{dT}$	
4-5.1 —	compressibility	κ	$\kappa = -\frac{1}{V}\frac{dV}{dp}$	
4-6.1 (4-4.1)	heat, quantity of heat	Q		The heat transferred in an isothermal phase transformation, formerly called "latent heat" with symbol L, is better expressed as the change of the appropriate thermodynamic functions, e.g. $T \cdot \Delta S$, where ΔS is the change of entropy, or as ΔH
4-7.1 (4-5.1)	heat flow rate	Φ	Rate of heat flow across a surface	
4-8.1 (4-6.1)	density of heat flow rate	q, φ	Heat flow rate divided by area	
4-9.1 (4-7.1)	thermal conductivity	λ, (k)	Density of heat flow rate divided by temperature gradient	
4-10.1 (4-8.1)	coefficient of heat transfer	h, k, K, α	Density of heat flow rate divided by temperature difference	[1] The symbols h and α are used for surface coefficient of heat transfer. The symbols k and K are used for overall coefficient of heat transfer
4-11.1 —	thermal insulance, coefficient of thermal insulation	M	Temperature difference divided by density of heat flow rate	

4. Heat (continued)

Units
4-3.a . . . 4-11.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
4-3.a	reciprocal kelvin, kelvin to the power minus one	K^{-1}			
4-4.a	pascal per kelvin	Pa/K			
4-5.a	reciprocal pascal, pascal to the power minus one	Pa^{-1}			
4-6.a	joule	J			For other units, see 3-24.b and c
4-7.a	watt	W			
4-8.a	watt per square metre	W/m^2			
4-9.a	watt per metre kelvin	W/(m·K)			
4-10.a	watt per square metre kelvin	$W/(m^2 \cdot K)$			
4-11.a	square metre kelvin per watt	$m^2 \cdot K/W$			

Quantities
4-12.1 . . . 4-18.1

4. Heat (continued)

Item No.	Quantity	Symbol	Definition	Remarks
4-12.1 —	thermal resistance	R	Temperature difference divided by heat flow rate	The quantity $G = 1/R$ is called thermal conductance
4-13.1 (4-9.1)	thermal diffusivity	a, (α, κ)	$a = \frac{\lambda}{\varrho c_p}$ where λ is thermal conductivity, ϱ is density, and c_p is specific heat capacity at constant pressure	
4-14.1 (4-10.1)	heat capacity	C	When the temperature of a system is increased by dT as a result of the addition of a small quantity of heat dQ, the quantity dQ/dT is the heat capacity	This quantity is not completely defined unless the type of change is specified
4-15.1 (4-11.1)	specific heat capacity	c	Heat capacity divided by mass	For the corresponding molar quantities, see part VIII
4-15.2 (4-11.2)	specific heat capacity at constant pressure	c_p		
4-15.3 (4-11.3)	specific heat capacity at constant volume	c_V		
4-15.4 —	specific heat capacity at saturation	c_{sat}		
4-16.1 (4-12.1)	ratio of the specific heat capacities	γ	$\gamma = c_p/c_V$	These quantities are dimensionless
4-16.2 —	isentropic exponent	κ	$\kappa = -\frac{V}{p}\left(\frac{\partial p}{\partial V}\right)_S$	For an ideal gas, γ is equal to κ
4-17.1 (4-13.1)	entropy	S	When a small quantity of heat dQ is received by a system the thermodynamic temperature of which is T, the entropy of the system is increased by dQ/T, provided that no irreversible change takes place in the system	
4-18.1 (4-14.1)	specific entropy	s	Entropy divided by mass	For the corresponding molar quantities, see part VIII

4. Heat (continued)

Units
4-12.a . . . 4-18.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
4-12.a	kelvin per watt	K/W			
4-13.a	square metre per second	m^2/s			
4-14.a	joule per kelvin	J/K			
4-15.a	joule per kilogram kelvin	J/(kg·K)			
4-17.a	joule per kelvin	J/K			
4-18.a	joule per kilogram kelvin	J/(kg·K)			

Quantities
4-19.1 . . . 4-22.1

4. Heat (concluded)

Item No.	Quantity	Symbole	Definition	Remarks
4-19.1 (4-15.1)	internal energy	U, (E)		
4-19.2 (4-15.2)	enthalpy	H, (U)	$H = U + pV$	
4-19.3 (4-15.3)	Helmholtz free energy, Helmholtz function	A, F	$A = U - TS$	
4-19.4 (4-15.4)	Gibbs free energy, Gibbs function	G	$G = U + pV - TS$	$G = H - TS$
4-20.1 (4-16.1)	specific internal energy	u, (e)	Internal energy divided by mass	For the corresponding molar quantities, see part VIII
4-20.2 (4-16.2)	specific enthalpy	h, (i)	Enthalpy divided by mass	
4-20.3 (4-16.3)	specific Helmholtz free energy, specific Helmholtz function	a, f	Helmholtz free energy divided by mass	
4-20.4 (4-16.4)	specific Gibbs free energy, specific Gibbs function	g	Gibbs free energy divided by mass	
4-21.1 —	Massieu function	J	$J = -A/T$	
4-22.1 —	Planck function	Y	$Y = -G/T$	

4. Heat (concluded)

Units
4-19.a . . . 4-22.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
4-19.a	joule	J			
4-20.a	joule per kilogram	J/kg			
4-21.a	joule per kelvin	J/K			
4-22.a	joule per kelvin	J/K			

ANNEX A

UNITS BASED ON THE FOOT, POUND AND SECOND
AND SOME OTHER UNITS

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
4-1.1	thermodynamic temperature	4-1.A.a	degree Rankine : °R	$1\ °R = \frac{5}{9}\ K$
–	Fahrenheit temperature	4-2.A.a	degree Fahrenheit : °F	$\frac{t_F}{°F} = \frac{9}{5}\frac{t}{°C} + 32 = \frac{9}{5}\frac{T}{K} + 459{,}67$ The unit degree Fahrenheit is equal to the unit degree Rankine
4-6.1	heat, quantity of heat	4-6.A.a	British thermal unit : Btu	1 Btu = 778,169 ft·lbf = 1 055,06 J This is the only British thermal unit used in this annex. It is equal to the "International Table British thermal unit" adopted by the Fifth International Conference on Properties of Steam (London, July 1956). Besides this a number of "British thermal units" were formerly used.
4-7.1	heat flow rate	4-7.A.a	British thermal unit per hour : Btu/h	1 Btu/h = 0,293 071 W
4-9.1	thermal conductivity	4-9.A.a	British thermal unit per second foot degree Rankine : Btu/(s·ft·°R)	1 Btu/(s·ft·°R) = 6 230,64 W/(m·K)
4-10.1	coefficient of heat transfer	4-10.A.a	British thermal unit per second square foot degree Rankine : Btu/(s·ft²·°R)	1 Btu/(s·ft²·°R) = 20 441,7 W/(m²·K)
		4-10.A.b	British thermal unit per hour square foot degree Rankine : Btu/(h·ft²·°R)	1 Btu/(h·ft²·°R) = 5,678 26 W/(m²·K)
4-13.1	thermal diffusivity	4-13.A.a	square foot per second : ft²/s	1 ft²/s = 0,092 903 04 m²/s (exactly)
4-15.1	specific heat capacity	4-15.A.a	British thermal unit per pound degree Rankine : Btu/(lb·°R)	1 Btu/(lb·°R) = 4 186,8 J/(kg·K) (exactly)

ANNEX A (*concluded*)

UNITS BASED ON THE FOOT, POUND AND SECOND
AND SOME OTHER UNITS

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
4-18.1	specific entropy	4-18.A.a	British thermal unit per pound degree Rankine : Btu/(lb·°R)	1 Btu/(lb·°R) = 4 186,8 J/(kg·K) (exactly)
4-20.1	specific internal energy	4-.20.A.a	British thermal unit per pound : Btu/lb	1 Btu/lb = 2 326 J/kg (exactly)
4-20.2	specific enthalpy			
4-20.3	specific Helmholtz free energy, specific Helmholtz function			
4-20.4	specific Gibbs free energy, specific Gibbs function			

ANNEX B

OTHER UNITS GIVEN FOR INFORMATION, ESPECIALLY REGARDING THE CONVERSION FACTOR

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
4-6.1	heat, quantity of heat	4-6.B.a	15 °C calorie † : cal_{15}	1 cal_{15} is the amount of heat required to warm 1 g of air-free water from 14,5 °C to 15,5 °C at a constant pressure of 101,325 kPa 1 cal_{15} = 4,185 5 J The International Union of Pure and Applied Physics in 1934 published a similar definition for the "gramme-calorie". The conversion factor shown above was proposed by the Comité consultatif de thermométrie et calorimétrie and adopted by the Comité international des poids et mesures (1950) as being the most accurate value which could then be deduced from experiment. This factor is uncertain by 0,000 5 J
		4-6.B.b	I.T. calorie † : cal_{IT}	For this I.T. calorie (International Table calorie) the Fifth International Conference on Properties of Steam (London, July 1956) adopted the definition 1 cal_{IT} = 4,186 8 J 1 $Mcal_{IT}$ = 1,163 kW·h (exactly)
		4-6.B.c	thermochemical calorie † : cal_{th}	1 cal_{th} = 4,184 J (exactly)
4-9.1	thermal conductivity	4-9.B.a	I.T. calorie per second centimetre kelvin † : $cal_{IT}/(s \cdot cm \cdot K)$	1 $cal_{IT}/(s \cdot cm \cdot K)$ = 418,68 W/(m·K) (exactly)
		4-9.B.b	thermochemical calorie per second centimetre kelvin † : $cal_{th}/(s \cdot cm \cdot K)$	1 $cal_{th}/(s \cdot cm \cdot K)$ = 418,4 W/(m·K) (exactly)
4-10.1	coefficient of heat transfer	4-10.B.a	I.T. calorie per second square centimetre kelvin † : $cal_{IT}/(s \cdot cm^2 \cdot K)$	1 $cal_{IT}/(s \cdot cm^2 \cdot K)$ = 4,186 8 x 10^4 W/(m^2·K) (exactly)
		4-10.B.b	thermochemical calorie per second square centimetre kelvin † : $cal_{th}/(s \cdot cm^2 \cdot K)$	1 $cal_{th}/(s \cdot cm^2 \cdot K)$ = 4,184 x 10^4 W/(m^2·K) (exactly)

The use of those units marked with † is deprecated.

ANNEX B (*concluded*)

OTHER UNITS GIVEN FOR INFORMATION, ESPECIALLY REGARDING THE CONVERSION FACTOR

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
4-15.1	specific heat capacity	4-15.B.a	I.T. calorie per gram kelvin † : $cal_{IT}/(g \cdot K)$	1 $cal_{IT}/(g \cdot K)$ = 4 186,8 J/(kg·K) (exactly)
		4-15.B.b	thermochemical calorie per gram kelvin † : $cal_{th}/(g \cdot K)$	1 $cal_{th}/(g \cdot K)$ = 4 184 J/(kg·K) (exactly)
4-18.1	specific entropy	4-18.B.a	I.T. calorie per gram kelvin † : $cal_{IT}/(g \cdot K)$	1 $cal_{IT}/(g \cdot K)$ = 4 186,8 J/(kg·K) (exactly)
		4-18.B.b	thermochemical calorie per gram kelvin † : $cal_{th}/(g \cdot K)$	1 $cal_{th}/(g \cdot K)$ = 4 184 J/(kg·K) (exactly)
4-20.1	specific internal energy	4-20.B.a	I.T. calorie per gram † : cal_{IT}/g	1 cal_{IT}/g = 4 186,8 J/kg (exactly)
		4-20.B.b	thermochemical calorie per gram † : cal_{th}/g	1 cal_{th}/g = 4 184 J/kg (exactly)

The use of those units marked with † is deprecated.

Quantities and units of electricity and magnetism

INTRODUCTION

This document, containing a table of *quantities and units of electricity and magnetism*, is part V of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General introduction — General principles concerning quantities, units and symbols.*

Part I : *Quantities and units of space and time.*

Part II : *Quantities and units of periodic and related phenomena.*

Part III : *Quantities and units of mechanics.*

Part IV : *Quantities and units of heat.*

Part V : *Quantities and units of electricity and magnetism.*

Part VI : *Quantities and units of light and related electromagnetic radiations.*

Part VII : *Quantities and units of acoustics.*

Part VIII : *Quantities and units of physical chemistry and molecular physics.*

Part IX : *Quantities and units of atomic and nuclear physics.*

Part X : *Quantities and units of nuclear reactions and ionizing radiations.*

Part XI : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand page.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases, only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing.

1) When two types of sloping letters exist (for example as with θ, ϑ; φ, ϕ; ϱ, g), only one of these is given; this does not mean that the other is not equally acceptable.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also Part 0.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicitly mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. The annexes are not integral parts of the standards. They are arranged in three groups :

a) *Units of the CGS system with special names*

It is generally preferable not to use CGS units with special names and symbols together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference for Weights and Measures has classified the SI units, radian and steradian, as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether angle and solid angle are to be considered as base quantities or derived quantities.

In ISO 31, plane angle and solid angle are treated as derived quantities (see also Part 0). In ISO 31, they are defined as ratios of two lengths and two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[1)]

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

SPECIAL REMARKS

Items in the field of electrotechnology in this document are generally in conformity with the recommendations in IEC Publication 27-1. If a name or a symbol in a table is not in accordance with what is given by IEC, this is indicated in the Remarks column.

Equations and quantities

For electricity and magnetism, different systems of equations have been developed depending on the number and the particular choice of base quantities on which the system of equations is founded. For the purpose of explaining this document, only the following systems need be mentioned :

I. System of equations with four base quantities

In the four-dimensional system of equations with four base quantities, one electric quantity is included in the base set. The base quantities are chosen to be : length, time, mass and electric current. In this system the permittivity and the permeability appear as dimensional quantities in the relevant equations.

The equations are always written in a form which is called rationalized, because in the equations factors 4π and 2π appear only in cases involving spherical or circular symmetry respectively.

1) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

This rationalized system of equations based on four base quantities is most commonly used in practical calculations in physical sciences and technology.

The use of this system is especially recommended.

II. Systems of equations with three base quantities

These are presented for information in annexes A and B, which are not integral parts of the International Standard. They are not given by IEC in Publication 27-1.

Units

The quantities which belong to the four-dimensional system should be measured in units of the sub-system of the International System of Units[1)] with the four base units :

metre, kilogram, second and ampere.

Alternating current technology

Items 5-40.1 to 5-44.1 in the table deal with sinusoidally varying quantities. For such quantities, lower-case letters are used for instantaneous values, upper-case letters are used for effective (root-mean-square) values, and lower-case letters with a subscript m are used for maximum values. For other choices of symbols and for further information, including cases where the quantities are not sinusoidal, see IEC Publication 27.

1) See also ISO 1000.

Quantities
5-1.1 . . . 5-7.1

5. Electricity and Magnetism

Item No.	Number in IEC Publication 27-1	Quantity	Symbol	Definition	Remarks
5-1.1	67	electric current	I		In alternating current technology, i is used for the instantaneous value of electric current
5-2.1	52	electric charge, quantity of electricity	Q	Integral of electric current over time	
5-3.1	54	volume density of charge, charge density	ρ, (η)	Charge divided by volume	IEC does not give "charge density"
5-4.1	53	surface density of charge	σ	Charge divided by surface area	
5-5.1	55	electric field strength	E, (K)	Force, exerted by electric field on an electric point charge, divided by the electric charge	
5-6.1	56	electric potential	V, φ	For electrostatic fields, a scalar quantity, the gradient of which, with reversed sign, is equal to the electric field strength	IEC gives φ as reserve symbol
5-6.2	57	potential difference, tension	U, (V)	The potential difference between point 1 and point 2 is the line integral from 1 to 2 of the electric field strength : $\varphi_1 - \varphi_2 = \int_1^2 E_s \, ds$	In alternating current technology, u is used for the instantaneous value of potential difference. IEC also gives "voltage"
5-6.3	58	electromotive force	E	The electromotive force of a source is the energy supplied by the source divided by the electric charge transported through the source	
5-7.1	60	electric flux density, displacement	D	The electric flux density is a vector quantity, the divergence of which is equal to the charge density	See 5-10.1

5. Electricity and Magnetism

Units
5-1.a . . . 5-7.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-1.a	ampere	A	The ampere is that constant electric current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length		
5-2.a	coulomb	C	1 C = 1 A·s		The unit ampere hour, 1 A·h = 3,6 kC, is sometimes used
5-3.a	coulomb per cubic metre	C/m³			
5-4.a	coulomb per square metre	C/m²			
5-5.a	volt per metre	V/m	1 V/m = 1 N/C		
5-6.a	volt	V	1 V = 1 W/A		
5-7.a	coulomb per square metre	C/m²			

Quantities
5-8.1 . . . 5-17.1

5. Electricity and magnetism (continued)

Item No.	Number in IEC Publication 27-1	Quantity	Symbol	Definition	Remarks
5-8.1 (5-9.1)	59	electric flux, (flux of displacement)	Ψ	The electric flux across a surface element is the scalar product of the surface element and the electric flux density	IEC does not give "(flux of displacement)"
5-9.1 (5-11.1)	61	capacitance	C	Charge divided by potential difference	
5-10.1 (5-12.1)	62	permittivity	ϵ	Electric flux density divided by electric field strength	IEC also gives "absolute permittivity, (capacitivity)"
5-10.2 (5-12.2)	206	permittivity of vacuum, electric constant	ϵ_0		$\epsilon_0 = 1/\mu_0 c^2$ = (8,854 187 818 ± 0,000 000 071) x 10^{-12} F/m[1] IEC recommends that if distinction is made between permittivity of vacuum and electric constant, the symbol Γ_e be used for the latter
5-11.1 (5-14.1)	63	relative permittivity	ϵ_r	$\epsilon_r = \epsilon/\epsilon_0$	This quantity is dimensionless. IEC also gives "(relative capacitivity)"
5-12.1 (5-15.1)	63a	electric susceptibility	χ, χ_e	$\chi = \epsilon_r - 1$	This quantity is dimensionless
5-13.1 (5-17.1)	65	electric polarization	P	$P = D - \epsilon_0 E$	IEC gives D_i as reserve symbol
5-14.1 (5-18.1)	66	electric dipole moment	p, (p_e)	The electric dipole moment is a vector quantity, the vector product of which with the electric field strength is equal to the torque	
5-15.1 (5-19.1)	68	current density	J, (S)	A vector quantity the integral of which over a given surface is equal to the current flowing through that surface	j is also used
5-16.1 (5-20.1)	69	linear current density	A, (α)	Current divided by the width of conducting sheet	
5-17.1 (5-21.1)	70	magnetic field strength	H	The magnetic field strength is an axial vector quantity, the curl (rotation) of which is equal to the current density, including the displacement current	

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5. Electricity and Magnetism (continued)

Units
5-8.a . . . 5-17.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-8.a	coulomb	C			
5-9.a	farad	F	1 F = 1 C/V		
5-10.a	farad per metre	F/m			
5-13.a	coulomb per square metre	C/m²			
5-14.a	coulomb metre	C·m			
5-15.a	ampere per square metre	A/m²			
5-16.a	ampere per metre	A/m			
5-17.a	ampere per metre	A/m			

Quantities
5-18.1 . . . 5-23.2

5. Electricity and Magnetism (continued)

Item No.	Number in IEC Publication 27-1	Quantity	Symbol	Definition	Remarks
5-18.1 (5-23.1)	71	magnetic potential difference	U_m	The magnetic potential difference between point 1 and point 2 is the line integral from 1 to 2 of the magnetic field strength	IEC gives also U as symbol and $\mathscr{U}$ as reserve symbol
5-18.2 (5-23.2)	72	magnetomotive force	F, F_m	$F = \oint H_s \, ds$	IEC gives $\mathscr{F}$ as reserve symbol.
5-18.3 (–)	72 a	current linkage	Θ	The net electric conduction current through a closed loop	When Θ results from N equal currents I, $\Theta = NI$
5-19.1 (5-24.1)	73	magnetic flux density, magnetic induction	B	The magnetic flux density is an axial vector quantity such that the force exerted on an element of current is equal to the vector product of this element and the magnetic flux density	
5-20.1 (5-25.1)	74	magnetic flux	Φ	The magnetic flux across a surface element is the scalar product of the surface element and the magnetic flux density	
5-21.1 (5-26.1)	75	magnetic vector potential	A	The magnetic vector potential is a vector quantity, the curl (rotation) of which is equal to the magnetic flux density	
5-22.1 (5-27.1)	76	self inductance	L	For a conducting loop, the magnetic flux through the loop, caused by the current in the loop, divided by this current	
5-22.2 (5-27.2)	77	mutual inductance	M, L_{12}	For two conducting loops, the magnetic flux through one loop, due to the current in the other loop, divided by this current	
5-23.1 (5-28.1)	78	coupling coefficient	k, (κ)	$k = L_{12}/\sqrt{L_1 L_2}$	These quantities are dimensionless
5-23.2 (5-28.2)	79	leakage coefficient	σ	$\sigma = 1 - k^2$	

5. Electricity and Magnetism (continued)

Units
5-18.a . . . 5-22.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-18.a	ampere	A			
5-19.a	tesla	T	1 T = 1 N/(A·m) = 1 Wb/m² = 1 V·s/m²		
5-20.a	weber	Wb	1 Wb = 1 V·s		
5-21.a	weber per metre	Wb/m			
5-22.a	henry	H	1 H = 1 Wb/A = 1 V·s/A		

Quantities
5-24.1 . . . 5-33.1

5. Electricity and Magnetism (continued)

Item No.	Number in IEC Publication 27-1	Quantity	Symbol	Definition	Remarks
5-24.1 (5-29.1)	80	permeability	μ	Magnetic flux density divided by magnetic field strength	IEC also gives "absolute permeability"
5-24.2 (5-29.2)	207	permeability of vacuum, magnetic constant	μ_0		$\mu_0 = 4\pi \cdot 10^{-7}$ H/m = 12,566 370 614 4 $\times 10^{-7}$ H/m[1] IEC recommends that if distinction is made between permeability in vacuum and magnetic constant, the symbol Γ_m be used for the latter
5-25.1 (5-31.1)	81	relative permeability	μ_r	$\mu_r = \mu/\mu_0$	This quantity is dimensionless
5-26.1 (5-32.1)	82	magnetic susceptibility	κ, (χ_m)	$\kappa = \mu_r - 1$	This quantity is dimensionless
5-27.1 (5-34.1)	83	electromagnetic moment (magnetic moment)	m	The electromagnetic moment is a vector quantity, the vector product of which with the magnetic flux density is equal to the torque	IEC gives "magnetic moment (magnetic area moment)" IEC also defines the quantity magnetic dipole moment, $j = \mu_0 m$
5-28.1 (5-35.1)	84	magnetization	H_i, M	$H_i = (B/\mu_0) - H$	
5-29.1 (5-36.1)	85	magnetic polarization	B_i, J	$B_i = B - \mu_0 H$	IEC also gives "intrinsic magnetic flux density"
5-30.1 (5-38.1)	(42)	electromagnetic energy density	w	Electromagnetic field energy divided by volume	
5-31.1 (5-39.1)	102	Poynting vector	S	The Poynting vector is equal to the vector product of electric field strength and magnetic field strength	
5-32.1 (5-40.1)	201	velocity of propagation of electromagnetic waves in vacuum	c		$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = (2,997\,924\,58 \pm 0,000\,000\,012) \times 10^8$ m/s[1] If the symbol c is used for the velocity in a medium, c_0 should be used for the velocity in vacuum. IEC gives only c_0 for the velocity in a vacuum, and gives c for the velocity in any medium.
5-33.1 (5-41.1)	87	resistance (to direct current)	R	Electric potential difference divided by current when there is no electromotive force in the conductor	

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5. Electricity and Magnetism (continued)

Units
5-24.a . . . 5-33.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-24.a	henry per metre	H/m	1 H/m = 1 Wb/(A·m) = 1 V·s/(A·m)		
5-27.a	ampere metre squared	A·m²			The quantity magnetic dipole moment has the unit Wb·m
5-28.a	ampere per metre	A/m			
5-29.a	tesla	T	1 T = 1 Wb/m² = 1 V·s/m²		
5-30.a	joule per cubic metre	J/m³			
5-31.a	watt per square metre	W/m²			
5-32.a	metre per second	m/s			
5-33.a	ohm	Ω	1 Ω = 1 V/A		

Quantities
5-34.1 . . . 5-41.4

5. Electricity and Magnetism (continued)

Item No.	Number in IEC Publication 27-1	Quantity	Symbol	Definition	Remarks
5-34.1 (5-42.1)	89	conductance (to direct current)	G	$G = 1/R$	
5-35.1 (5-43.1)	88	resistivity	ρ	Electric field strength divided by current density when there is no electromotive force in the conductor	
5-36.1 (5-44.1)	90	conductivity	γ, σ	$\gamma = 1/\rho$	κ is used in electrochemistry
5-37.1 (5-45.1)	91	reluctance	R, R_m	Magnetic potential difference divided by magnetic flux	IEC gives $\mathscr{R}$ as a reserve symbol
5-38.1 (5-46.1)	92	permeance	$\Lambda, (P)$	$\Lambda = 1/R_m$	
5-39.1 (5-47.1)	104	number of turns in a winding	N		These quantities are dimensionless
5-39.2 (5-47.2)	105	number of phases	m		
5-39.3 (5-47.3)	106	number of pairs of poles	p		
5-40.1 (5-48.1)	103	phase difference, phase displacement	φ	When $u = u_m \cos \omega t$ and $i = i_m \cos(\omega t - \varphi)$ then φ is the phase displacement	Remark to 5-40.1 . . . 5-44.1 See also Introduction, Special Remark on "Alternating current technology" This quantity is dimensionless See also Introduction, Remark on supplementary units $\omega t - \varphi$ is called the phase of i IEC gives θ as a reserve symbol
5-41.1 (5-49.1)	93	impedance, (complex impedance)	Z	The complex representation of potential difference divided by the complex representation of current	$Z = \lvert Z \rvert e^{j\varphi} = R + jX$
5-41.2 (5-94.2)	93	modulus of impedance, (impedance)	$\lvert Z \rvert$		$\lvert Z \rvert = \sqrt{R^2 + X^2}$
5-41.3 (5-49.3)	94	reactance	X	Imaginary part of impedance	$X = L\omega - \frac{1}{C\omega}$ for an inductive reactance and a capacitive reactance in series See 5-33.1
5-41.4 (5-49.4)	87	resistance	R	Real part of impedance	

5. Electricity and Magnetism (continued)

Units
5-34.a . . . 5-41.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-34.a	siemens	S	1 S = 1A/V		1 S = 1 Ω^{-1}
5-35.a	ohm metre	$\Omega \cdot m$			
5-36.a	siemens per metre	S/m			
5-37.a	reciprocal henry, henry to the power minus one	H^{-1}	1 H^{-1} = 1 A/Wb		
5-38.a	henry	H	1 H = 1 Wb/A		
5-40.a	radian	rad			See also the Introduction
5-41.a	ohm	Ω	1 Ω = 1 V/A		

Quantities
5-42.1 . . . 5-44.1

5. Electricity and Magnetism (concluded)

Item No.	Number in IEC Publication 27-1	Quantity	Symbol	Definition	Remarks
5-42.1 (5-50.1)	95	quality factor	Q	$Q = \lvert X \rvert / R$	This quantity is dimensionless
5-43.1 (5-51.1)	97	admittance, (complex admittance)	Y	$Y = 1/Z$	$Y = \lvert Y \rvert \, e^{-j\varphi} = G + jB = \frac{R - jX}{\lvert Z \rvert^2}$
5-43.2 (5-51.2)	97	modulus of admittance, (admittance)	$\lvert Y \rvert$		$\lvert Y \rvert = \sqrt{G^2 + B^2}$
5-43.3 (5-51.3)	98	susceptance	B	Imaginary part of admittance	
5-43.4 (5-51.4)	89	conductance	G	Real part of admittance	See 5-34.1
5-44.1 (5-52.1)	99	power	P	Product of current and potential difference	When $u = u_m \cos \omega t = \sqrt{2}\, U \cos \omega t$ and $i = i_m \cos (\omega t - \varphi)$ $= \sqrt{2}\, I \cos (\omega t - \varphi)$ then $i\,u$ is the instantaneous power (symbol : p) $I\,U \cos \varphi$ is the active power (symbol : P) $I\,U$ is the apparent power [symbol : S, (P_s)] $I\,U \sin \varphi$ is the reactive power [symbol : Q, (P_q)] The name "power factor", (symbol : λ), is used for the ratio P/S

5. Electricity and Magnetism (concluded)

Units
5-43.a . . . 5-44.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-43.a	siemens	S	1 S = 1 A/V		
5-44.a	watt	W	1 W = 1 J/s = 1 V·A		In electric power technology, active power is expressed in watts (W), apparent power in volt-amperes (V·A) and reactive power in vars (var)

ANNEX A[1)]

THREE-DIMENSIONAL EQUATIONS AND QUANTITIES

Different three-dimensional systems of equations have been developed for electric and magnetic quantities based on the three base quantities : length, time and mass. Only the so-called Gaussian or "symmetric" system of equations is still used. They are also given for information in the IUPAP-SUN Publication, 1977.

Physical quantities defined through this system of equations in terms of the three base quantities will be called Gaussian quantities.

The symbol chosen for each Gaussian quantity is that of the corresponding quantity in the system with four base quantities, with the subscript s added.

The Gaussian system of equations defines the electric charge as a derived physical quantity, on the basis of Coulomb's law for the force between two electric charges, by taking the permittivity to be a dimensionless quantity equal to unity in vacuum. The velocity of light appears explicitly in some of the equations combining electric and magnetic quantities in such a way that the permeability turns out to be a dimensionless quantity equal to unity in vacuum. The Gaussian system of equations is written in non-rationalized form.

The relation of the Gaussian quantities to the corresponding four-dimensional quantities is always given in the "Remarks" column on the left-hand page.

Some of the essential equations of the Gaussian system are given in annex B.

The Gaussian quantities which belong to the three-dimensional Gaussian system are commonly measured in units of the Gaussian CGS system with the three base units :

centimetre, gram and second.

1) Annex A is not an integral part of the standard.

Gaussian quantities
5-1.1$_s$ . . . 5-6.1$_s$

ANNEX A

Item No.	Quantity	Symbol	Definition	Remarks
5-1.1$_s$	Gaussian electric current	I_s	Gaussian electric charge crossing a surface divided by time	$I_s = I/(4\pi\epsilon_0)^{1/2}$ $\epsilon_0 = 10^{11}\,\zeta^{-2}\,(4\pi)^{-1}$ F/m For ζ, see 5-1.a$_s$
5-2.1$_s$	Gaussian electric charge, Gaussian quantity of electricity	Q_s	The Gaussian electric charge is defined by $F = Q_{s1}\,Q_{s2}/r^2$ where F is the force in vacuum and r is the distance between two points with Gaussian electric charges Q_{s1} and Q_{s2}	$Q_s = Q/(4\pi\epsilon_0)^{1/2}$
5-5.1$_s$	Gaussian electric field strength	E_s, (K_s)	Force, exerted by electric field on an electric charge, divided by the Gaussian electric charge	$E_s = E(4\pi\epsilon_0)^{1/2}$
5-6.1$_s$	Gaussian electric potential	V_s, φ_s	For electrostatic fields, a scalar quantity, the gradient of which, with reversed sign, is equal to the Gaussian electric field strength	$V_s = V(4\pi\epsilon_0)^{1/2}$

ANNEX A

Gaussian units
5-1.a$_s$ . . . 5-6.a$_s$

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-1.a$_s$	Gaussian CGS unit of electric current		1 Gaussian CGS unit of electric current $= 1\ \mathrm{cm^{3/2}\cdot g^{1/2}\cdot s^{-2}}$		When $I_s = 1\ \mathrm{cm^{3/2}\cdot g^{1/2}\cdot s^{-2}}$ the electric current is $I = 10\,\zeta^{-1}$ A $= 3{,}335\,64 \times 10^{-10}$ A The number ζ is defined by $c = \zeta$ cm/s where c is the velocity of light in vacuum. In this document the value of ζ is taken as $\zeta = 2{,}997\,924\,58 \times 10^{10}$
5-2.a$_s$	Gaussian CGS unit of electric charge		This unit of charge, being that Gaussian electric charge which exerts on an equal charge at a distance of 1 centimetre in vacuum a force of 1 dyne, is equal to $1\ \mathrm{cm^{3/2}\cdot g^{1/2}\cdot s^{-1}}$		When $Q_s = 1\ \mathrm{cm^{3/2}\cdot g^{1/2}\cdot s^{-1}}$ the electric charge is $Q = 10\,\zeta^{-1}$ C $= 3{,}335\,64 \times 10^{-10}$ C For ζ, see the remark to 5-1.a$_s$
5-5 a$_s$	Gaussian CGS unit of electric field strength		1 Gaussian CGS unit of electric field strength $= 1\ \mathrm{cm^{-1/2}\cdot g^{1/2}\cdot s^{-1}}$		When $E_s = 1\ \mathrm{cm^{-1/2}\cdot g^{1/2}\cdot s^{-1}}$ the electric field strength is $E = 10^{-6}\,\zeta$ V/m $= 2{,}997\,925 \times 10^{4}$ V/m For ζ, see the remark to 5-1.a$_s$
5-6.a$_s$	Gaussian CGS unit of electric potential		1 Gaussian CGS unit of electric potential $= 1\ \mathrm{cm^{1/2}\cdot g^{1/2}\cdot s^{-1}}$		When $V_s = 1\ \mathrm{cm^{1/2}\cdot g^{1/2}\cdot s^{-1}}$ the electric potential is $V = 10^{-8}\,\zeta$ V $= 2{,}997\,925 \times 10^{2}$ V For ζ, see the remark to 5-1.a$_s$

Gaussian quantities
5-7.1$_s$ . . . 5-19.1$_s$

ANNEX A (*continued*)

Item No.	Quantity	Symbol	Definition	Remarks
5-7.1$_s$	Gaussian electric flux density	D_s	The Gaussian electric flux density is a vector quantity, the divergence of which is equal to 4 π times the Gaussian charge density	This quantity is sometimes called electric induction $D_s = D\,(4\pi/\epsilon_0)^{1/2}$
5-9.1$_s$	Gaussian capacitance	C_s	Gaussian charge divided by Gaussian potential difference	$C_s = C/4\pi\epsilon_0$
5-11.1$_s$	Gaussian permittivity	ϵ_s	Gaussian electric flux density divided by the Gaussian electric field strength	This quantity is dimensionless The Gaussian permittivity is identical with the relative permittivity $\epsilon_s = \epsilon_r = \epsilon/\epsilon_0$
5-12.1$_s$	Gaussian electric susceptibility	χ_s	$\chi_s = (\epsilon_r - 1)/4\pi$	This quantity is dimensionless $\chi_s = (4\pi)^{-1}\chi$
5-13.1$_s$	Gaussian electric polarization	P_s	$4\pi P_s = D_s - E_s$	$P_s = P/(4\pi\epsilon_0)^{1/2}$
5-17.1$_s$	Gaussian magnetic field strength	H_s	The Gaussian magnetic field strength is a vector quantity, the curl (rotation) of which is equal to $4\pi/c$ times the current density, including the displacement current	$H_s = (H/c)\,(4\pi/\epsilon_0)^{1/2}$ $= H\,(4\pi\mu_0)^{1/2}$
5-19.1$_s$	Gaussian magnetic flux density, Gaussian magnetic induction	B_s	The Gaussian magnetic flux density is a vector quantity such that the force exerted on an element of current is equal to $(1/c)$ times the vector product of the element of Gaussian electric current and the Gaussian magnetic flux density	$B_s = Bc\,(4\pi\epsilon_0)^{1/2}$ $= B\,(4\pi/\mu_0)^{1/2}$

ANNEX A (*continued*)

Gaussian units
5-7.a$_s$ . . . 5-19.a$_s$

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-7.a$_s$	Gaussian CGS unit of displacement		1 Gaussian CGS unit of displacement $= 1\ \mathrm{cm}^{-1/2}\cdot\mathrm{g}^{1/2}\cdot\mathrm{s}^{-1}$		When $D_s = 1\ \mathrm{cm}^{-1/2}\cdot\mathrm{g}^{1/2}\cdot\mathrm{s}^{-1}$ the displacement is $D = 10^5\,\zeta^{-1}\,(4\pi)^{-1}\ \mathrm{C/m^2}$ $= 2{,}654\,42 \times 10^{-7}\ \mathrm{C/m^2}$ For ζ, see the remark to 5-1.a$_s$
5-9.a$_s$	Gaussian CGS unit of capacitance, centimetre	cm	1 Gaussian CGS unit of capacitance = 1 cm		When $C_s = 1$ cm, the capacitance is $C = 10^9\,\zeta^{-2}\ \mathrm{F}$ $= 1{,}112\,65 \times 10^{-12}\ \mathrm{F}$ For ζ, see the remark to 5-1.a$_s$
5-13.a$_s$	Gaussian CGS unit of electric polarization		1 Gaussian CGS unit of electric polarization $= 1\ \mathrm{cm}^{-1/2}\cdot\mathrm{g}^{1/2}\cdot\mathrm{s}^{-1}$		When $P_s = 1\ \mathrm{cm}^{-1/2}\cdot\mathrm{g}^{1/2}\cdot\mathrm{s}^{-1}$ the polarization is $P = 10^5\,\zeta^{-1}\ \mathrm{C/m^2}$ $= 3{,}335\,64 \times 10^{-6}\ \mathrm{C/m^2}$ For ζ, see the remark to 5-1.a$_s$
5-17.a$_s$	Gaussian CGS unit of magnetic field strength, oersted	Oe	$1\ \mathrm{Oe} = 1\ \mathrm{cm}^{-1/2}\cdot\mathrm{g}^{1/2}\cdot\mathrm{s}^{-1}$		When $H_s = 1$ Oe, the magnetic field strength is $H = 10^3\,(4\pi)^{-1}\ \mathrm{A/m}$ $= 79{,}577\,5\ \mathrm{A/m}$
5-19.a$_s$	Gaussian CGS unit of magnetic flux density, gauss	Gs	$1\ \mathrm{Gs} = 1\ \mathrm{cm}^{-1/2}\cdot\mathrm{g}^{1/2}\cdot\mathrm{s}^{-1}$		When $B_s = 1$ Gs, the magnetic flux density is $B = 10^{-4}\ \mathrm{T}$ The symbol G is used in physics

Gaussian quantities
5-20.1$_s$ . . . 5-28.1$_s$

ANNEX A (*concluded*)

Item No.	Quantity	Symbol	Definition	Remarks
5-20.1$_s$	Gaussian magnetic flux	Φ_s	The Gaussian magnetic flux across a surface element is the scalar product of the surface element and the Gaussian magnetic flux density	$\Phi_s = \Phi c (4\pi\epsilon_0)^{1/2}$ $= \Phi (4\pi/\mu_0)^{1/2}$
5-25.1$_s$	Gaussian permeability	μ_s	Gaussian magnetic flux density divided by the Gaussian magnetic field strength	This quantity is dimensionless The Gaussian permeability is identical with the relative permeability $\mu_s = \mu_r = \mu/\mu_0$
5-26.1$_s$	Gaussian magnetic susceptibility	κ_s	$\kappa_s = (\mu_s - 1)/4\pi$	This quantity is dimensionless $\kappa_s = (4\pi)^{-1}\kappa$
5-28.1$_s$	Gaussian magnetization	M_s	$M_s = (B_s - H_s)/4\pi$	$M_s = M(\mu_0/4\pi)^{1/2}$ $= J(1/4\pi\mu_0)^{1/2}$

ANNEX A (*concluded*)

Gaussian units
5-20.a$_s$ . . . 5-28.a$_s$

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
5-20.a$_s$	Gaussian CGS unit of magnetic flux, maxwell	Mx	1 Mx = 1 cm$^{3/2}$ · g$^{1/2}$ · s^{-1}		When Φ_s = 1 Mx, the magnetic flux is $\Phi = 10^{-8}$ Wb
5-28.a$_s$	Gaussian CGS unit of magnetization		1 Gaussian CGS unit of magnetization = 1 cm$^{-1/2}$ · g$^{1/2}$ · s^{-1}		When M_s = 1 cm$^{-1/2}$ · g$^{1/2}$ · s^{-1} the magnetization is $M = 10^3$ A/m and the magnetic polarization is $J = 4\pi \cdot 10^{-4}$ T = 1,256 64 x 10^{-3} T

ANNEX B[1) 2)]

EXAMPLES OF RELATIONS IN DIFFERENT SYSTEMS OF EQUATIONS

In this annex, symbols for vector quantities are printed in bold face; see page 1.

Quantities occurring in the second column of equations which differ from the corresponding quantities in the first column of equations are provided with a subscript s (symmetric).

Item No.	Subject	Rationalized system of equations with four base quantities (The system of the standard)	Gaussian system of equations with three base quantities (The system of annex A)
1	Maxwell's equations	$\operatorname{rot} \boldsymbol{E} = -\partial \boldsymbol{B}/\partial t$	$c \operatorname{rot} \boldsymbol{E}_s = -\partial \boldsymbol{B}_s/\partial t$
2		$\operatorname{div} \boldsymbol{D} = \varrho$	$\operatorname{div} \boldsymbol{D}_s = 4\pi \varrho_s$
3		$\operatorname{div} \boldsymbol{B} = 0$	$\operatorname{div} \boldsymbol{B}_s = 0$
4		$\operatorname{rot} \boldsymbol{H} = \boldsymbol{J} + \partial \boldsymbol{D}/\partial t$	$c \operatorname{rot} \boldsymbol{H}_s = 4\pi \boldsymbol{J}_s + \partial \boldsymbol{D}_s/\partial t$
5	Force on charge Q in electric field $\boldsymbol{E}$	$\boldsymbol{F} = Q\boldsymbol{E}$	$\boldsymbol{F} = Q_s \boldsymbol{E}_s$
6	Relation between $\boldsymbol{E}$ and $\boldsymbol{D}$	$\varepsilon_0 \varepsilon_r \boldsymbol{E} = \varepsilon \boldsymbol{E} = \boldsymbol{D}$	$\varepsilon_r \boldsymbol{E}_s = \boldsymbol{D}_s$
7	Electric flux density at distance r from charge Q	$D = Q/4\pi r^2$	$D_s = Q_s/r^2$
8	Electric flux density at surface with surface density of charge σ	$D = \sigma$	$D_s = 4\pi\sigma_s$
9	Force between charges Q_1 and Q_2 at distance r in dielectric	$F = Q_1 Q_2/4\pi\varepsilon r^2$	$F = Q_{s1} Q_{s2}/\varepsilon_r r^2$
10	Capacitance of two parallel plates, area A, distance d	$C = A\varepsilon/d$	$C_s = A\varepsilon_r/4\pi d$
11	Capacitance of isolated sphere, radius r	$C = 4\pi\varepsilon r$	$C_s = \varepsilon_r r$
12	Relation between $\boldsymbol{E}$ and V in electrostatics	$\boldsymbol{E} = -\operatorname{grad} V$	$\boldsymbol{E}_s = -\operatorname{grad} V_s$
13	Poisson's equation in electrostatics in vacuum	$\Delta V = -\varrho/\varepsilon_0$	$\Delta V_s = -4\pi\varrho_s$
14	Potential at distance r from charge Q in vacuum	$V = Q/4\pi\varepsilon_0 r$	$V_s = Q_s/r$
15	Potential at position $\boldsymbol{r}$ of electric dipole in vacuum	$V = \boldsymbol{p} \cdot \boldsymbol{r}/4\pi\varepsilon_0 r^3$	$V_s = \boldsymbol{p}_s \cdot \boldsymbol{r}/r^3$
16	Electric dipole moment of charges $\pm Q$, separated by s	$\boldsymbol{p} = Q\boldsymbol{s}$	$\boldsymbol{p}_s = Q_s \boldsymbol{s}$
17	Potential energy of electric dipole in electric field	$W = -\boldsymbol{p} \cdot \boldsymbol{E}$	$W = -\boldsymbol{p}_s \cdot \boldsymbol{E}_s$
18	Electric dipole moment of volume element $\Delta\tau$ with polarization $\boldsymbol{P}$	$\boldsymbol{p} = \boldsymbol{P}\Delta\tau$	$\boldsymbol{p}_s = \boldsymbol{P}_s \Delta\tau$
19	Energy density of electric field	$w = \boldsymbol{D} \cdot \boldsymbol{E}/2$	$w = \boldsymbol{D}_s \cdot \boldsymbol{E}_s/8\pi$
20	Force on charge Q moving with velocity $\boldsymbol{v}$ in magnetic field	$\boldsymbol{F} = Q\boldsymbol{v} \times \boldsymbol{B}$	$\boldsymbol{F} = Q_s \boldsymbol{v} \times \boldsymbol{B}_s/c$
21	Force on current element $I\Delta\boldsymbol{s}$ in magnetic field	$\boldsymbol{F} = I\Delta\boldsymbol{s} \times \boldsymbol{B}$	$\boldsymbol{F} = I_s \Delta\boldsymbol{s} \times \boldsymbol{B}_s/c$
22	Relation between $\boldsymbol{B}$ and $\boldsymbol{H}$	$\boldsymbol{B} = \mu_0 \mu_r \boldsymbol{H} = \mu \boldsymbol{H}$	$\boldsymbol{B}_s = \mu_r \boldsymbol{H}_s$
23	Magnetic field strength due to moving charge Q	$\boldsymbol{H} = Q\boldsymbol{v} \times \boldsymbol{r}/4\pi r^3$	$\boldsymbol{H}_s = Q_s \boldsymbol{v} \times \boldsymbol{r}/cr^3$
24	Magnetic field strength due to current element $I\Delta\boldsymbol{s}$	$\boldsymbol{H} = I\Delta\boldsymbol{s} \times \boldsymbol{r}/4\pi r^3$	$\boldsymbol{H}_s = I_s \Delta\boldsymbol{s} \times \boldsymbol{r}/cr^3$
25	Magnetic field strength at distance r from linear conductor	$H = I/2\pi r$	$H_s = 2I_s/cr$
26	Magnetic field strength in solenoid with N turns on length l	$H = NI/l$	$H_s = 4\pi N I_s/cl$
27	Force between two parallel linear conductors at distance d in vacuum	$F/l = \mu_0 I_1 I_2/2\pi d$	$F/l = 2I_{s1} I_{s2}/c^2 d$
28	Relation between $\boldsymbol{B}$ and vector potential $\boldsymbol{A}$	$\boldsymbol{B} = \operatorname{rot} \boldsymbol{A}$	$\boldsymbol{B}_s = \operatorname{rot} \boldsymbol{A}_s$
29	Wave equation for vector potential in vacuum	$\Delta \boldsymbol{A} - \frac{1}{c^2}\frac{\partial^2 \boldsymbol{A}}{\partial t^2} = -\mu_0 \boldsymbol{J}$	$\Delta \boldsymbol{A}_s - \frac{1}{c^2}\frac{\partial^2 \boldsymbol{A}_s}{\partial t^2} = -\frac{4\pi}{c}\boldsymbol{J}_s$
30	Gauge condition for $\boldsymbol{A}$	$\operatorname{div} \boldsymbol{A} + \frac{1}{c^2}\frac{\partial V}{\partial t} = 0$	$\operatorname{div} \boldsymbol{A}_s + \frac{1}{c}\frac{\partial V_s}{\partial t} = 0$
31	General relation between $\boldsymbol{E}$, V and $\boldsymbol{A}$	$\boldsymbol{E} = -\operatorname{grad} V - \frac{\partial \boldsymbol{A}}{\partial t}$	$\boldsymbol{E}_s = -\operatorname{grad} V_s - \frac{1}{c}\frac{\partial \boldsymbol{A}_s}{\partial t}$
32	Electromagnetic moment of current I surrounding a plane area A	$m = IA$	$m_s = I_s A/c$
33	Potential energy of magnetic dipole in magnetic field	$W = -\boldsymbol{m} \cdot \boldsymbol{B}$	$W = -\boldsymbol{m}_s \cdot \boldsymbol{B}_s$
34	Electromagnetic moment of volume element $\Delta\tau$ with magnetization $\boldsymbol{M}$	$\boldsymbol{m} = \boldsymbol{M}\Delta\tau$	$\boldsymbol{m}_s = \boldsymbol{M}_s \Delta\tau$
35	Energy density of magnetic field	$w = \boldsymbol{B} \cdot \boldsymbol{H}/2$	$w = \boldsymbol{B}_s \cdot \boldsymbol{H}_s/8\pi$
36	Poynting vector	$\boldsymbol{S} = \boldsymbol{E} \times \boldsymbol{H}$	$\boldsymbol{S} = (c/4\pi)\boldsymbol{E}_s \times \boldsymbol{H}_s$

1) Also given in the IUPAP-SUN Publication, 1977.
2) Annex B is not an integral part of the standard.

Quantities and units of light and related electromagnetic radiations

Introduction

This document, containing a table of *quantities and units of light and related electromagnetic radiations*, is part 6 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When a preferred symbol and a reserve symbol are given, the reserve symbol is in parentheses.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also ISO 31/0.

(1) When two types of sloping letters exist (for example as with θ; ϑ; φ; ϕ; g; g) only one of these is given; this does not mean that the other is not equally acceptable.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicity mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. These annexes are not integral parts of the standards. They are arranged in three groups :

a) *Units of the CGS system with special names*

It is generally preferable not to use the special names and symbols of CGS units together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference of Weights and Measures has classified the SI units radian and steradian as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.(1)

In ISO 31, plane angle and solid angle are treated as derived quantities (see also ISO 31/0). In ISO 31, they are defined as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements(2)

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits, and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

Special remarks

Quantities

This document contains a selection of quantities pertaining to light, many of which are also useful for the whole range of electromagnetic radiations. For light, mainly photometric quantities are given.

In several cases, the same symbol is used for a pair of corresponding radiant and luminous quantities with the understanding that subscripts e for energetic and v for visible will be added whenever confusion between these quantities might otherwise occur.

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

(2) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

For ionizing radiations, however, see ISO 31/10.

In this document spectral concentrations in terms of wavelength correspond to several quantities. The definition is given explicitly in 6-8.1 and the relation to 6-7.1 is shown in the remarks column. Other spectral concentrations are indicated by equations in the remarks column. The subscript λ is used as part of the symbol to indicate that the quantity has the dimension of a derivative with respect to λ. Spectral concentrations in terms of frequency or wave number are defined and denoted similarly, the subscript λ being replaced by ν or σ respectively. Spectral concentrations are also called distribution functions, for example wavelength distribution function, frequency distribution function. The name of a quantity which is a spectral concentration may be shortened by replacing the words "spectral concentration of" by the adjective "spectral", for example spectral concentration of radiant energy density may be called spectral radiant energy density.

The adjective "spectral" is also used to designate quantities which are functions of wavelength (or frequency or wave number), but which are not spectral concentrations, for example spectral emissivity, see 6-18.2. The functional dependence is usually indicated by including λ (or ν or σ) in parentheses as part of the symbol, for example $\varepsilon(\lambda)$.

Units

In photometry, the supplementary unit steradian is used for convenience.

6. Light and related electromagnetic radiations

Quantities
6-1.1 . . . 6-11.1

Item No.	Quantity	Symbol	Definition	Remarks
6-1.1	frequency	f, ν	Number of cycles divided by time.	
6-2.1	circular frequency	ω	$\omega = 2\pi\nu$	
6-3.1	wavelength	λ	Distance in the direction of propagation of a periodic wave between two successive points at which the phase is the same (at the same time).	The wavelength in a medium is equal to the wavelength *in vacuo* divided by the refractive index of the medium, see 6-33.1.
6-4.1 6-4.2	wavenumber, repetency circular wavenumber, circular repetency	σ k	$\sigma = 1/\lambda$ $k = 2\pi\sigma$	In molecular spectroscopy $\tilde{\nu}$ is also used for ν/c_0.
6-5.1	velocity (speed) of propagation of electromagnetic waves *in vacuo*	c, c_0		$c = (2{,}997\ 924\ 58 \pm 0{,}000\ 000\ 012) \times 10^8$ m/s[1] Sometimes c is used for the phase velocity in a medium, in which case c_0 is used for the velocity *in vacuo*.
6-6.1	radiant energy	Q, W, (U, Q_e)	Energy emitted, transferred or received as radiation.	
6-7.1	radiant energy density	w, (u)	Radiant energy in an element of volume, divided by that element.	For non-polarized black body (full) radiation $w_\lambda = 8\pi hc \cdot f(\lambda, T)$ and $w = \frac{4\sigma}{c} T^4$. For $f(\lambda, T)$ and σ, see 6-16.1, 6-17.1 and 6-15.1, respectively $w = \int w_\lambda \, d\lambda$ See also the introduction, special remarks.
6-8.1	spectral concentration of radiant energy density (in terms of wavelength), spectral radiant energy density (in terms of wavelength)	w_λ	The radiant energy density in an infinitesimal wavelength interval, divided by the range of that interval.	
6-9.1	radiant power, radiant energy flux	P, Φ, (Φ_e)	Power emitted, transferred or received as radiation.	$\Phi = \int \Phi_\lambda \, d\lambda$
6-10.1	radiant energy fluence rate	φ, ψ	At a given point in space, the radiant energy flux incident on a small sphere, divided by the cross-sectional area of that sphere.	$\varphi = \int \varphi_\lambda \, d\lambda$ In an isotropic homogeneous radiation field, φ/c is the energy density, and the irradiance of a surface is $\varphi/4$.
6-11.1	radiant intensity	I, (I_e)	In a given direction from a source, the radiant energy flux leaving the source, or an element of the source, in an element of solid angle containing the given direction, divided by that element of solid angle.	$I = \int I_\lambda \, d\lambda$

(1) CODATA Bulletin 11 (1973). Recommended for universal use by the 15th CGPM (1975).

6. Light and related electromagnetic radiations

Units
6-1.a . . . 6-11.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
6-1.a	hertz	Hz	1 Hz = 1 s^{-1}		
6-2.a	reciprocal second, second to the power minus one	s^{-1}			
6-2.b	radian per second	rad/s			
6-3.a	metre	m			
6-3.b	Ångström	Å	1 Å = 10^{-10} m	1 Å = 10^{-10} m (exactly)	10 Å = 1 nm
6-4.a	reciprocal metre, metre to the power minus one	m^{-1}			The multiple cm^{-1} is often used.
6-5.a	metre per second	m/s			
6-6.a	joule	J	1 J = 1 $kg \cdot m^2/s^2$		
6-7.a	joule per cubic metre	J/m^3			
6-8.a	joule per metre to the fourth power	J/m^4			
6-9.a	watt	W	1 W = 1 J/s		
6-10.a	watt per square metre	W/m^2			
6-11.a	watt per steradian	W/sr			For steradian, see the introduction.

6. Light and related electromagnetic radiations (continued)

Quantities
6-12.1 . . . 6-17.1

Item No.	Quantity	Symbol	Definition	Remarks
6-12.1	radiance	L, (L_e)	At a point of a surface and in a given direction, the radiant intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction.	$L = \int L_\lambda \, d\lambda$ For non-polarized black body (full) radiation $L_\lambda = \frac{c}{4\pi} w_\lambda = 2hc^2 \cdot f(\lambda, T)$ and $L = \frac{\sigma}{\pi} T^4$. For $f(\lambda, T)$ and σ, see 6-16.1, 6-17.1 and 6-15.1 respectively.
6-13.1	radiant exitance	M, (M_e)	At a point of a surface, the radiant energy flux leaving an element of the surface, divided by the area of that element.	Formerly called radiant emittance. $M = \int M_\lambda \, d\lambda$ For non-polarized black body (full) radiation $M_\lambda = \frac{c}{4} w_\lambda = 2\pi hc^2 \cdot f(\lambda, T)$ and $M = \sigma \cdot T^4$. For $f(\lambda, T)$ and σ, see 6-16.1, 6-17.1 and 6-15.1 respectively.
6-14.1	irradiance	E, (E_e)	At a point of a surface, the radiant energy flux incident on an element of the surface, divided by the area of that element.	$E = \int E_\lambda \, d\lambda$
6-15.1	Stefan-Boltzmann constant	σ	The constant σ in the expression for the radiant exitance of a full radiator (black body) at the thermodynamic temperature T: $M = \sigma \cdot T^4$	$\sigma = \frac{2\pi^5 k^4}{15 h^3 c^2}$ $= (5{,}670\,32 \pm 0{,}000\,71) \times 10^{-8}$ W/(m^2.K^4) (1) For k and h, see ISO 31/8 and ISO 31/9 respectively.
6-16.1	first radiation constant	c_1	The constants c_1 and c_2 in the expression for the spectral concentration of the radiant exitance of a full radiator (black body) at the thermodynamic temperature T: $M_\lambda = c_1 f(\lambda, T) = c_1 \frac{\lambda^{-5}}{\exp(c_2/\lambda T) - 1}$	$c_1 = 2\pi hc^2$ $= (3{,}741\,832 \pm 0{,}000\,020) \times 10^{-16}$ W·m^2 (1) The name first radiation constant has also been used for the factors $8\pi hc$ and hc^2 in the corresponding expressions for w_λ and L_λ (see also remark 6-8.1 and 6-12.1).
6-17.1	second radiation constant	c_2		$c_2 = \frac{hc}{k}$ $= (1{,}438\,786 \pm 0{,}000\,045) \times 10^{-2}$ m·K (1) For expressing temperatures in the "International Practical Temperature Scale of 1968", as adopted by the Comité International des Poids et Mesures, the numerical value $1{,}438\,8 \times 10^{-2}$ should be used.

(1) CODATA Bulletin 11 (1973).

6. Light and related electromagnetic radiations (continued)

Units
6-12.a . . . 6-17.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
6-12.a	watt per steradian square metre	W/(sr·m^2)			
6.13.a	watt per square metre	W/m^2			
6.14.a —	watt per square metre	W/m^2			
6.15.a	watt per square metre kelvin to the fourth power	W/(m^2·K^4)			
6-16.a	watt square metre	W·m^2			
6.17.a	metre kelvin	m·K			

6. Light and related electromagnetic radiations (continued)

Quantities
6-18.1 . . . 6-25.1

Item No.	Quantity	Symbol	Definition	Remarks
6-18.1	emissivity	ε	Ratio of radiant exitance of a thermal radiator to that of a full radiator (black body) at the same temperature.	These quantities are dimensionless.
6-18.2	spectral emissivity, emissivity at a specified wavelength	$\varepsilon(\lambda)$	Ratio of spectral concentration of radiant exitance of a thermal radiator to that of a full radiator (black body) at the same temperature.	The spectral emissivity is a function of wavelength; this is indicated by the symbol $\varepsilon(\lambda)$.
6-18.3	directional spectral emissivity	$\varepsilon(\lambda, \theta, \varphi)$	Ratio of spectral concentration of radiance in a given direction θ, φ of a thermal radiator to that of a full radiator (black body) at the same temperature.	
6-19.1	luminous intensity	I, (I_v)		See also 6-20.1. $I = \int I_\lambda \mathrm{d}\lambda$
6-20.1	luminous flux	Φ, (Φ_v)	The luminous flux $\mathrm{d}\Phi$ of a source of luminous intensity I in an element of solid angle $\mathrm{d}\Omega$ is $\mathrm{d}\Phi = I\mathrm{d}\Omega$.	$\Phi = \int \Phi_\lambda \mathrm{d}\lambda$ The luminous flux Φ is related to the spectral concentration of radiant energy flux $\Phi_{e\lambda}$ by the equation : $\Phi = \int K(\lambda)\, \Phi_{e\lambda} \mathrm{d}\lambda$ where $K(\lambda)$ is the luminous efficacy, see 6-26.2 and 6-27.2.
6-21.1	quantity of light	Q, (Q_v)	Time integral of luminous flux.	$Q = \int Q_\lambda \mathrm{d}\lambda$
6-22.1	luminance	L, (L_v)	At a point of a surface and in a given direction, the luminous intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction.	$L = \int L_\lambda \mathrm{d}\lambda$
6-23.1	luminous exitance	M, (M_v)	At a point of a surface, the luminous flux leaving an element of the surface, divided by the area of that element.	Formerly called luminous emittance. $M = \int M_\lambda \mathrm{d}\lambda$
6-24.1	illuminance	E, (E_v)	At a point of a surface, the luminous flux incident on an element of the surface, divided by the area of that element.	$E = \int E_\lambda \mathrm{d}\lambda$
6-25.1	light exposure	H	$H = \int E \mathrm{d}t$	Formerly called quantity of illumination.

6. Light and related electromagnetic radiations (continued)

Units
6-19.a . . . 6-25.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
6-19.a	candela	cd	The candela is the luminous intensity in a given direction of a source which emits monochromatic radiation of frequency 540×10^{12} hertz and of which the radiant intensity in that direction is 1/683 watt per steradian.		
6-20.a	lumen	lm	1 lm = 1 cd·sr		
6-21.a	lumen second	lm·s			
6-21.b	lumen hour	lm·h		1 lm·h = 3 600 lm·s (exactly)	
6-22.a	candela per square metre	cd/m^2			
6-23.a	lumen per square metre	lm/m^2			
6-24.a	lux	lx	1 lx = 1 lm/m^2		
6-25.a	lux second	lx·s			
6-25.b	lux hour	lx·h		1 lx·h = 3 600 lx·s (exactly)	

6. Light and related electromagnetic radiations (continued)

Quantities
6-26.1 . . . 6-29.1

Item No.	Quantity	Symbol	Definition	Remarks
6-26.1	luminous efficacy	K	$K = \dfrac{\Phi_v}{\Phi_e}$	$K = \dfrac{\int \Phi_{v\lambda}\mathrm{d}\lambda}{\int \Phi_{e\lambda}\mathrm{d}\lambda} = \dfrac{\int K(\lambda)\Phi_{e\lambda}\mathrm{d}\lambda}{\int \Phi_{e\lambda}\mathrm{d}\lambda}$
6-26.2	spectral luminous efficacy, luminous efficacy at a specified wavelength	$K(\lambda)$	$K(\lambda) = \dfrac{\Phi_{v\lambda}}{\Phi_{e\lambda}}$	For the notation $K(\lambda)$, see remark 6-18.2.
6-26.3	maximum spectral luminous efficacy	K_m	The maximum value of $K(\lambda)$.	For a monochromatic radiation of frequency 540×10^{12} Hz, the spectral luminous efficacy is equal to 683 lm/W.
6-27.1	luminous efficiency	V	$V = \dfrac{K}{K_m}$	These quantities are dimensionless. $V = \dfrac{\int V(\lambda)\Phi_{e\lambda}\mathrm{d}\lambda}{\int \Phi_{e\lambda}\mathrm{d}\lambda}$
6-27.2	spectral luminous efficiency, luminous efficiency at a specified wavelength	$V(\lambda)$	$V(\lambda) = \dfrac{K(\lambda)}{K_m}$	For the notation $V(\lambda)$, see remark 6-18.2. $\Phi_v = \int K(\lambda)\Phi_{e\lambda}\mathrm{d}\lambda = K_m \cdot \int V(\lambda)\Phi_{e\lambda}\mathrm{d}\lambda$ Standard values of $V(\lambda)$ relating to the light-adapted eye were adopted by the International Commission on Illumination in 1971 and approved by the Comité International des Poids et Mesures in 1972. Procès-Verbaux du CIPM 40 (1972) 29, 145.
6-28.1	CIE spectral tristimulus values	$x(\lambda)$, $y(\lambda)$, $z(\lambda)$	Thrichromatic components, in the "CIE (XYZ) thrichromatic system", of monochromatic light stimuli of equal energy. These functions are applicable to fields of observation of angular opening between 1° and 4°. For this standard colorimetric system $y(\lambda) \overset{\text{def}}{=} V(\lambda)$.	These quantities are dimensionless. Formerly CIE-distribution coefficients. In 1964 the CIE adopted a supplementary standard colorimetric system with spectral tristimulus values $x_{10}(\lambda)$, $y_{10}(\lambda)$, $z_{10}(\lambda)$ applicable to fields of observation of angular subtense greater than 4°.
6-29.1	chromaticity co-ordinates	x, y, z	For the relative spectral energy or power distribution $\varphi(\lambda)$ $x = \dfrac{\int \varphi(\lambda)\bar{x}(\lambda)\mathrm{d}\lambda}{\int \varphi(\lambda)\bar{x}(\lambda)\mathrm{d}\lambda + \int \varphi(\lambda)\bar{y}(\lambda)\mathrm{d}\lambda + \int \varphi(\lambda)\bar{z}(\lambda)\mathrm{d}\lambda}$ and similar expressions for y and z. For light sources $\varphi(\lambda) = \Phi_{e\lambda}(\lambda)/\Phi_{e\lambda}(\lambda_0)$ (relative spectral radiant energy flux). For object colours $\varphi(\lambda)$ is given by one of the three products $\varphi(\lambda) = \dfrac{\Phi_{e\lambda}(\lambda)}{\Phi_{e\lambda}(\lambda_0)} \cdot \begin{cases} \varrho(\lambda) \\ \tau(\lambda) \\ \beta(\lambda) \end{cases}$	These quantities are dimensionless. $\varphi(\lambda)$ is called colour tristimulus function. λ_0 is a reference wavelength. In the CIE 1964 supplementary standard colorimetric system, the symbols for the chromaticity co-ordinates are x_{10}, y_{10}, z_{10}.

6. Light and related electromagnetic radiations (continued)

Unit
6-26.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
6-26.a	lumen per watt	lm/W			

6. Light and related electromagnetic radiations (concluded)

Quantities
6-30.1 . . . 6-33.1

Item No.	Quantity	Symbol	Definition	Remarks
6-30.1	spectral absorption factor, spectral absorptance	$\alpha(\lambda)$	Ratio of the spectral concentration of radiant or luminous flux absorbed to that of the incident radiation.	These quantities are dimensionless. For the notation $\alpha(\lambda)$ etc., see remark 6-18.2.
6-30.2	spectral reflection factor, spectral reflectance	$\varrho(\lambda)$	Ratio of the spectral concentration of radiant or luminous flux reflected to that of the incident radiation.	The symbols α, ϱ, τ and β are used for weighted averages of $\alpha(\lambda)$, $\varrho(\lambda)$, $\tau(\lambda)$, and $\beta(\lambda)$ respectively; the adjective spectral is then dropped from the names.
6-30.3	spectral transmission factor, spectral transmittance	$\tau(\lambda)$	Ratio of the spectral concentration of radiant or luminous flux transmitted to that of the incident radiation.	The weighting will be different for the radiant and luminous factors.
6-30.4	spectral radiance factor	$\beta(\lambda)$	At a point of a surface and in a given direction the ratio of the spectral concentration of radiance of a non-self-radiating body to that of a perfect diffuser under identical irradiation conditions.	See also the introduction.
6-31.1	linear attenuation coefficient, linear extinction coefficient	μ, μ_l	The relative decrease in spectral concentration of the radiant or luminous flux of a collimated beam of electromagnetic radiation during traversal of an infinitesimal layer of a medium, divided by the length traversed.	μ/ϱ where ϱ is the density of the medium, is called mass attenuation coefficient.
6-31.2	linear absorption coefficient	a	The part of the linear attenuation coefficient that is due to absorption.	a/ϱ, where ϱ is the density of the medium, is called mass absorption coefficient.
6-32.1	molar absorption coefficient	κ	$\kappa = \frac{a}{c}$ where c is the amount-of-substance concentration.	For amount-of-substance concentration, see ISO 31/8.
6-33.1	refractive index	n	For a non-absorbing medium, the ratio of the velocity of electromagnetic radiation in vacuo to the phase velocity of electromagnetic radiation of a specified frequency in the medium.	This quantity is dimensionless.

6. Light and related electromagnetic radiations (concluded)

Units
6-31.a . . . 6-32.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
6-31.a	reciprocal metre, metre to the power minus one	m^{-1}			
6-32.a	square metre per mole	m^2/mol			

Quantities and units of acoustics

INTRODUCTION

This document, containing a table of *quantities and units of acoustics*, is part VII of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General introduction – General principles concerning quantities, units and symbols.*

Part I : *Quantities and units of space and time.*

Part II : *Quantities and units of periodic and related phenomena.*

Part III : *Quantities and units of mechanics.*

Part IV : *Quantities and units of heat.*

Part V : *Quantities and units of electricity and magnetism.*

Part VI : *Quantities and units of light and related electromagnetic radiations.*

Part VII : *Quantities and units of acoustics.*

Part VIII : *Quantities and units of physical chemistry and molecular physics.*

Part IX : *Quantities and units of atomic and nuclear physics.*

Part X : *Quantities and units of nuclear reactions and ionizing radiations.*

Part XI : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also part 0.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicitly mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

1) When two types of sloping letters exist (for example as with ϑ, θ; φ, ϕ; and g, g) only one of these is given. This does not mean that the other is not equally acceptable.

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. The annexes are not integral parts of the standard. They are arranged in three groups :

a) *Units of the CGS-system with special names*

It is generally preferable not to use CGS-units with special names and symbols together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The Conférence générale des poids et mesures (CGPM : General Conference for Weights and Measures) has classified the SI units, radian and steradian, as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether angle and solid angle are to be considered as base quantities or derived quantities.

In ISO 31, plane angle and solid angle are treated as derived quantities (see also part 0). They are defined in ISO 31 as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[1]

All numbers in the column "Definition" are exact.

In the column "Conversion factors" the conversion factors on which the calculation of others are based are normally given to seven significant digits. When they are exact and contain seven or fewer digits and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

SPECIAL REMARKS

The explanations in the "Definition" column for quantities presuppose, in general, linear systems.

When it is necessary to use subscripts to avoid confusion between similar symbols in different domains, the subscript "a" is recommended for the acoustical case.

Remark on level difference

In ISO 31, level difference is defined as the natural logarithm of the ratio of two quantities of the same kind. It is a dimensionless quantity. Although the coherent unit corresponding to this definition is the number 1, it is convenient in practice to use the special namer neper.

The expression for level difference in terms of Briggsian logarithms follows from the definition.

The relation between the neper and the decibel, the units commonly used for expressing level difference, is

$$1\ \mathrm{dB} = \frac{\ln 10}{20}\ \mathrm{Np}$$

The relation between the bel and decibel is $1\ \mathrm{dB} = 10^{-1}\ \mathrm{B}$, but only the decibel is given in ISO 31 since the bel is not often used.

1) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

7. Acoustics

Quantities
7-1.1 . . . 7-12.1

Item No.	Quantity	Symbol	Definition	Remarks
7-1.1	period, periodic time	T	Time of one cycle	
7-2.1	frequency	f, ν	$f = 1/T$	Concerning the standard tuning frequency (standard musical pitch), see ISO 16
7-3.1	frequency interval		The frequency interval between two frequencies is the logarithm of the ratio of the higher frequency to the lower frequency	This quantity is dimensionless
7-4.1	angular frequency, circular frequency, pulsatance	ω	$\omega = 2\pi f$	
7-5.1	wavelength	λ		
7-6.1	circular wave number	k	$k = 2\pi/\lambda$ $= 2\pi\sigma$ where σ is the wave number, $\sigma = 1/\lambda$	The corresponding vector quantity is called propagation vector
7-7.1	density (mass density)	ϱ	Mass divided by volume	
7-8.1	static pressure	p_s	Pressure that would exist in the absence of sound waves	The root mean square values of the quantities 7-8.2 to 7-12.1 are often called "effective" values, and the same symbols are often used without modification to denote the effective values.
7-8.2	(instantaneous) sound pressure	p, (p_a)	The difference between the instantaneous total pressure and the static pressure	
7-9.1	(instantaneous) sound particle displacement	ξ, (x)	Instantaneous displacement of a particle of the medium from what would be its position in the absence of sound waves	
7-10.1	(instantaneous) sound particle velocity	u, v	$u = \frac{\partial \xi}{\partial t}$	
7-11.1	(instantaneous) sound particle acceleration	a	$a = \frac{\partial u}{\partial t}$	
7-12.1	(instantaneous) volume flow rate, volume velocity	q, U	Instantaneous rate of volume flow due to the sound wave	

7. Acoustics

Units
7-1.a . . . 7-12. a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
7-1.a	second	s			
7-2.a	hertz	Hz	1 Hz is the frequency of a periodic phenomenon of which the period is 1 s		1 Hz = 1 s^{-1}
7-3.a	octave		The frequency interval between f_1 and f_2 is one octave if $f_2/f_1 = 2$		The numerical value of the frequency interval in octaves is given by lb (f_2/f_1), $(f_2 \geq f_1)$
7-4.a	reciprocal second, second to the power minus one	s^{-1}			
7-5.a	metre	m			
7-6.a	reciprocal metre, metre to the power minus one	m^{-1}			
7-7.a	kilogram per cubic metre	kg/m^3			
7-8.a	pascal	Pa			
7-8.b	bar	bar		1 bar = 10^5 Pa (exactly)	
7-9.a	metre	m			
7-10.a	metre per second	m/s			
7-11.a	metre per second squared	m/s^2			
7-12.a	cubic metre per second	m^3/s			

Quantities
7-13.1 . . . 7-18.1

7. Acoustics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
7-13.1	velocity of sound	c, (c_a)	Velocity of a sound wave	
7-14.1	sound energy density	w, (w_a), (E)	Mean sound energy in a given volume divided by that volume	If the energy density is varying with time, the mean must be taken over an interval during which the sound may be considered statistically stationary
7-15.1	sound energy flux, sound power	P, (P_a)	Sound energy transferred in a certain time interval, divided by the duration of that interval	
7-16.1	sound intensity	I, J	For unidirectional sound energy flux, sound energy flux through an area normal to the direction of propagation divided by that area	
7-17.1 (–)	characteristic impedance of a medium	Z_c	At a point in a medium and for a plane progressive wave, the complex representation of sound pressure divided by the complex representation of particle velocity	For a non-dissipative medium $Z_c = \varrho c$ In these definitions, 7-17.1 to 7-19.1, the quantities entering the numerators and denominators are here assumed to be sinusoidal.
7-17.2 (7-17.1)	specific acoustic impedance	Z_s	At a surface, the complex representation of sound pressure divided by the complex representation of particle velocity	$Z_s = \frac{Z_s}{S}$ $\quad Z_m = SZ_s$ where S is the area of the surface considered
7-18.1	acoustic impedance	Z_a	At a surface, the complex representation of sound pressure divided by the complex representation of volume flow rate	

7. Acoustics (continued)

Units
7-13.a . . . 7-18.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
7-13.a	metre per second	m/s			
7-14.a	joule per cubic metre	J/m³			
7-15.a	watt	W			
7-16.a	watt per square metre	W/m²			
7-17.a	pascal second per metre	Pa·s/m			
7-18.a	pascal second per metre cubed	Pa·s/m³			

Quantities
7-19.1 . . . 7-24.1

7. Acoustics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
7-19.1	mechanical impedance	Z_m	The complex representation of total force at a surface (or at a point) of a mechanical system divided by the complex representation of average particle velocity at that surface (or of particle velocity at that point) in the direction of the force	
7-20.1 (7-21.1)	sound pressure level	L_p	$L_p = \ln (p/p_0)$ $= \ln 10 \cdot \lg (p/p_0)$ where p and p_0 are a given sound pressure and a reference pressure, respectively	This quantity is dimensionless The reference pressure must be explicitly stated The subscript p is often omitted, especially when other subscripts are needed See also part II
7-21.1 (7-20.1)	sound power level	L_P, L_W	$L_P = \frac{1}{2} \ln (P/P_0)$ $= \frac{1}{2} \ln 10 \cdot \lg (P/P_0)$ where P and P_0 are a given sound power and a reference power, respectively	This quantity is dimensionless The reference power must be explicitly stated See also part II
7-22.1	damping coefficient	δ	If a quantity is a function of time t given by $F(t) = Ae^{-\delta t} \sin [\omega (t - t_0)]$ then δ is the damping coefficient	$\tau = 1/\delta$ is the time constant (relaxation time) of the amplitude
7-23.1 (–)	time constant, relaxation time	τ	$\tau = 1/\delta$, where δ is the damping coefficient	
7-24.1 (7-23.1)	logarithmic decrement	Λ	Product of damping coefficient and period	This quantity is dimensionless

7. Acoustics (continued)

Units
7-19.a . . . 7-24.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
7-19.a	newton second per metre	N·s/m			
7-20.a	decibel	dB	1 dB is the sound pressure level when $20 \lg (p/p_0) = 1$		The numerical value of L_p expressed in decibels is given by $20 \lg (p/p_0)$ See also the Introduction, "Remark on level difference"
7-21.a	decibel	dB	1 dB is the sound power level when $10 \lg (P/P_0) = 1$		The numerical value of L_P expressed in decibels is given by $10 \lg (P/P_0)$ See also the Introduction, "Remark on level difference"
7-22.a	reciprocal second, second to the power minus one	s^{-1}			
7-22.b	neper per second	Np/s			
7-23.a	second	s			
7-24.a	neper	Np			See the Introduction, "Remark on level difference"

7. Acoustics (continued)

Quantities
7-25.1 . . . 7-28.1

Item No.	Quantity	Symbol	Definition	Remarks
7-25.1 (7-24.1)	attenuation coefficient	α	If a quantity is a function of distance x given by $F(x) = Ae^{-\alpha x}\cos[\beta(x - x_0)]$ then α is the attenuation coefficient and β is the phase coefficient	The quantity $l = 1/\alpha$ is called the attenuation length
7-25.2 (7-24.2)	phase coefficient	β		The quantity $\beta(x - x_0)$ is called the phase
7-25.3 (7-24.3)	propagation coefficient	γ	$\gamma = \alpha + j\beta$	
7-26.1 (7-25.1)	dissipation coefficient	δ, (ψ)	Ratio of the sound energy flux dissipated to the incident sound energy flux	These quantities are dimensionless
7-26.2 (7-25.2)	reflection coefficient	r, ϱ	Ratio of the sound energy flux reflected to the incident sound energy flux	
7-26.3 (7-25.3)	transmission coefficient	τ	Ratio of the sound energy flux transmitted to the incident sound energy flux	$\delta + \varrho + \tau = 1$
7-26.4 (7-25.4)	acoustic absorption coefficient	α, (α_s)	$\alpha = \delta + \tau$	
7-27.1 (7-26.1)	sound reduction index, sound transmission loss	R	$R = \frac{1}{2}\ln(1/\tau)$ $= \frac{1}{2}\ln 10 \cdot \lg(1/\tau)$ where τ is the transmission coefficient	This quantity is dimensionless
7-28.1 (7-27.1)	equivalent absorption area of a surface or object	A	The equivalent absorption area of a surface or object in a diffuse sound field is that area of a surface having the acoustic absorption coefficient equal to 1, which, if diffraction effects are neglected, would, in the same diffuse sound field, absorb the same power	

7. Acoustics (continued)

Units
7-25.a . . . 7-28.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
7-25.a	reciprocal metre, metre to the power minus one	m^{-1}			
7-27.a	decibel	dB	1 dB is the sound reduction index when $10 \lg(1/\tau) = 1$		The numerical value of R expressed in decibels is given by $10 \lg(1/\tau)$
7-28.a	square metre	m^2			

7. Acoustics (concluded)

Quantities
7-29.1 . . . 7-31.1

Item No.	Quantity	Symbol	Definition	Remarks
7-29.1 (7-28.1)	reverberation time	T	Time required for the average sound energy density in an enclosure to decrease to 10^{-6} of the initial value (i.e. by 60 dB) after the source has stopped	
7-30.1 (7-29.1)	loudness level	L_N	$L_N = \ln\left(\frac{p_{eff}}{p_{o,eff}}\right)_{1\,kHz} = \ln 10 \cdot \lg(p_{eff}/p_o)_{1\,kHz}$ where p_{eff} is the effective (root-mean-square) sound pressure of a standard pure tone of 1 kHz which is judged by a normal observer under standardized listening conditions as being equally loud, and where $p_o = 2 \times 10^{-5}$ Pa = 20 μPa	See also part II These quantities are dimensionless These are not purely physical quantities, but entail subjective evaluation
7-31.1 (7-30.1)	loudness	N	The loudness is the normal observer's auditory estimate of the ratio between the strength of the sound considered and that of a reference sound having a loudness level of 40 phons	

7. Acoustics (concluded)

Units
7-29.a . . . 7-31.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
7-29.a	second	s			
7-30.a	phon		1 phon is the loudness level when $20 \lg (p_{eff}/p_o)_{1\,kHz} = 1$		The numerical value of L_N expressed in phons is given by $20 \lg (p_{eff}/p_o)_{1\,kHz}$
7-31.a	sone				A standard relation between loudness in sones and loudness level in phons has been adopted for practical use and is given in ISO/R 131

ANNEX

UNITS OF THE CGS-SYSTEM WITH SPECIAL NAMES

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
7-8.1	static pressure	7-8.A.a	dyne per square centimetre : dyn/cm^2	$1\ dyn/cm^2 = 10^{-1}\ Pa$ (exactly)
7-14.1	sound energy density	7-14.A.a	erg per cubic centimetre : erg/cm^3	$1\ erg/cm^3 = 10^{-1}\ J/m^3$ (exactly)
7-15.1	sound energy flux, sound power	7-15.A.a	erg per second : erg/s	$1\ erg/s = 10^{-7}\ W$ (exactly)
7-16.1	sound intensity	7-16.A.a	erg per second square centimetre : $erg/(s \cdot cm^2)$	$1\ erg/(s \cdot cm^2) = 10^{-3}\ W/m^2$ (exactly)
7-17.1	characteristic impedance of a medium	7-17.A.a	dyne second per centimetre cubed : $dyn \cdot s/cm^3$	$1\ dyn \cdot s/cm^3 = 10\ Pa \cdot s/m$ (exactly)
7-17.2	specific acoustic impedance	7-17.A.b		
7-18.1	acoustic impedance	7-18.A.a	dyne second per centimetre to the fifth : $dyn \cdot s/cm^5$	$1\ dyn \cdot s/cm^5 = 10^5\ Pa \cdot s/m^3$ (exactly)
7-19.1	mechanical impedance	7-19.A.a	dyne second per centimetre : $dyn \cdot s/cm$	$1\ dyn \cdot s/cm = 10^{-3}\ N \cdot s/m$ (exactly)

Quantities and units of physical chemistry and molecular physics

Introduction

This document, containing a table of *quantities and units of physical chemistry and molecular physics*, is part 8 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When a preferred symbol and a reserve symbol are given, the reserve symbol is in parentheses.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also ISO 31/0.

(1) When two types of sloping letters exist (for example as with $\dot{\theta}$: θ; φ: ϕ; g; g) only one of these is given; this does not mean that the other is not equally acceptable.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicity mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. These annexes are not integral parts of the standards. They are arranged in three groups :

1) *Units of the CGS system with special names*

It is generally preferable not to use the special names and symbols of CGS units together with SI units.

2) *Units based on the foot, pound and second and some other units*

3) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference of Weights and Measures has classified the SI units radian and steradian as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.(1)

In ISO 31, plane angle and solid angle are treated as derived quantities (see also ISO 31/0). In ISO 31, they are defined as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements(2)

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits, and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

Special remarks

In this document, symbols for substances are shown as subscripts, for example c_B, w_B, ρ_B.

If the symbol for the substance is complicated, it is advisable to put it in brackets on the same line as the main symbol, $c(H_2SO_4)$.

The superscript * is used to mean "pure". The superscript ° is used to mean "standard".

The names and symbols of the chemical elements are given in annex A.

In this document, the annexes are integral parts of the standard.

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

(2) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

Physical chemistry and molecular physics

8. Physical chemistry and molecular physics

Quantities
8-1.1 . . . 8-6.1

Item No.	Quantity	Symbol	Definition	Remarks
8-1.1	relative atomic mass of an element	A_r	The ratio of the average mass per atom of an element to 1/12 of the mass of an atom of nuclide ^{12}C.	These quantities are dimensionless. Example : $A_r(Cl) = 35,453$. Formerly called atomic weight.
8-1.2	relative molecular mass of a substance	M_r	The ratio of the average mass per molecule or specified entity of a substance to 1/12 of the mass of an atom of nuclide ^{12}C.	Formerly called molecular weight. The relative atomic or molecular mass depends on the nuclidic composition.
8-2.1	number of molecules or other elementary entities	N	Number of molecules or other elementary entities in a system.	This quantity is dimensionless.
8-3.1	amount of substance	n, (ν)		ν may be used as an alternative to n when n is used for number density of particles, see 8-10.1.
8-4.1	Avogadro constant	L, N_A	Number of molecules divided by the amount of substance.	$N_A = N/n$ $= (6,022\,045 \pm 0,000\,031) \times 10^{23}\ mol^{-1}$ (1)
8-5.1	molar mass	M	Mass divided by amount of substance.	$M = m/n$ where m is the mass of the substance.
8-6.1	molar volume	V_m	Volume divided by amount of substance.	$V_m = V/n$. The molar volume of an ideal gas at 273,15 K and 101,325 kPa is $V_{m,0} = (0,022\,413\,83 \pm 0,000\,000\,70)\ m^3/mol$ (1).

(1) CODATA Bulletin 11 (1973).

8. Physical chemistry and molecular physics

Units
8-3.a . . . 8-6.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-3.a	mole	mol	The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0,012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.		
8-4.a	reciprocal mole, mole to the power minus one	mol^{-1}			
8-5.a	kilogram per mole	kg/mol			$M = 10^{-3} M$, kg/mol $= M$, kg/kmol $= M$, g/mol where M_r is the relative molecular mass of a substance of definite chemical composition.
8-6.a	cubic metre per mole	m^3/mol			

Quantities
8-7.1 . . . 8-16.1

8. Physical chemistry and molecular physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
8-7.1	molar internal energy	U_m, (E_m)	Internal energy divided by amount of substance.	$U_m = U/n$. See ISO 31/4. Similar definitions apply to other molar thermodynamic functions, for example H_m, A_m, G_m.
8-8.1	molar heat capacity	C_m	Heat capacity divided by amount of substance.	$C_m = C/n$. See ISO 31/4.
8-9.1	molar entropy	S_m	Entropy divided by amount of substance.	$S_m = S/n$. See ISO 31/4.
8-10.1	number density of molecules (or particles)	n	The number of molecules or particles divided by volume.	$n = N/V$
8-10.2	molecular concentration of substance B	C_B	The number of molecules of substance B divided by the volume of the mixture.	
8-11.1	density, (mass density)	ϱ	Mass divided by volume.	
8-11.2	mass concentration of substance B	ϱ_B	Mass of substance B divided by the volume of the mixture.	
8-12.1	mass fraction of substance B	w_B	Ratio of the mass of substance B to the mass of the mixture.	This quantity is dimensionless.
8-13.1	concentration of substance B, amount-of-substance concentration of substance B	c_B	Amount of substance of substance B divided by the volume of the mixture.	In chemistry also indicated as [B].
8-14.1 (–)	volume fraction of substance B	φ_B	$\varphi_B = \frac{x_B V_{m,B}}{\Sigma_A x_A V_{m,A}}$ where $V_{m,B}$ is the molar volume of the pure substance B at the same temperature and pressure.	This quantity is dimensionless. An alternative definition in which the molar volumes $V_{m,B}$ of the pure substances B are replaced by the partial molar volumes $(\partial V/\partial n_B)_{T,p,n_{C\neq B}}$ of the substances B is also used. The partial molar volume of the pure substance B may be indicated by V_B^* and is identical with $V_{m,B}$.
8-15.1 (8-14.1)	mole fraction of substance B	x_B, (y_B)	Ratio of the amount of substance of substance B to the amount of substance of the mixture.	These quantities are dimensionless. Alternative names for these quantities are "amount-of-substance fraction" and "amount-of-substance ratio" respectively.
8-15.2 (8-14.2)	mole ratio of solute substance B	r_B	Ratio of the amount of substance of solute substance B to the amount of substance of the solvent substance.	For a one-solute solution $r = x/(1 - x)$.
8-16.1 (8-15.1)	molality of solute substance B	b_B, m_B	The amount of substance of solute substance B in a solution divided by the mass of the solvent.	

8. Physical chemistry and molecular physics (continued)

Units
8-7.a . . . 8-16.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-7.a	joule per mole	J/mol			For the calories, see ISO 31/4, annex B.
8-8.a	joule per mole kelvin	J/(mol·K)			
8-9.a	joule per mole kelvin	J/(mol·K)			
8-10.a	reciprocal cubic metre, metre to the power minus three	m^{-3}			
8-11.a	kilogram per cubic metre	kg/m^3			
8-11.b	kilogram per litre	kg/l, kg/L			The symbol L was adopted by the CGPM (1979) as an alternative to l for litre.
8-13.a	mole per cubic metre	mol/m^3			
8-13.b	mole per litre	mol/l, mol/L		1 mol/l = 10^3 mol/m^3 (exactly) = 1 mol/dm^3 (exactly)	
8-16.a	mole per kilogram	mol/kg			

8. Physical chemistry and molecular physics (continued)

Quantities
8-17.1 . . . 8-23.1

Item No.	Quantity	Symbol	Definition	Remarks
8-17.1 (8-16.1)	chemical potential of substance B	μ_B	For a mixture with component substances B, C,... $\mu_B = (\partial G/\partial n_B)_{T, p, n_C,...}$ where n_B is the amount of substance of substance B and G is the Gibbs function.	For a pure substance $\mu = G/n = G_m$ where G_m is the molar Gibbs free energy. The symbol μ is also used for the quantity G_m/N_A, where N_A is the Avogadro constant.
8-18.1 (8-17.1)	absolute activity of substance B	λ_B	$\lambda_B = \exp(\mu_B/RT)$	This quantity is dimensionless. For R and T, see 8-35.1.
8-19.1 (8-18.1)	partial pressure of substance B (in a gaseous mixture)	p_B	For a gaseous mixture $p_B = x_B \cdot p$ where p is the pressure.	
8-20.1 (8-19.1)	fugacity of substance B (in a gaseous mixture)	f_B, $\tilde{p}_B$	For a gaseous mixture, f_B is proportional to the absolute activity λ_B, the proportionality factor, which is a function of temperature only, being determined by the condition that at constant temperature and composition f_B/p_B tends to 1 for an infinitely dilute gas.	$f_B = \lambda_B \cdot \lim_{p \to 0} (x_B p/\lambda_B)$. (For the symbol, see also 8-22.1.1.
8-21.1 (–)	standard absolute activity of substance B (in a gaseous mixture)	$\lambda_B^\ominus$	$\lambda_B^\ominus = (p^\ominus/x_B) \lim_{p \to 0} (\lambda_B/p)$ where $p^\ominus$ is a standard pressure, usually 101,325 kPa.	This quantity is dimensionless. This quantity is a function only of temperature.
8-22.1 (8-20.1)	activity coefficient of substance B (in a liquid or a solid mixture)	f_B	For a liquid mixture $f_B = \lambda_B/(\lambda_B^* x_B)$ where λ^*_B is the absolute activity of the pure substance B at the same temperature and pressure.	These quantities are dimensionless. The name "activity factor" would be more systematic.
8-22.2 (–)	standard absolute activity of substance B (in a liquid or solid mixture)	$\lambda_B^\ominus$	$\lambda_B^\ominus = \lambda^*_B(p^\ominus)$	This quantity is a function only of temperature.
8-23.1 (8-21.1)	activity of solute substance B, relative activity of solute substance B (especially in a dilute liquid solution)	a_B, $a_{m,B}$	For a solute in a solution a_B is proportional to the absolute activity λ_B, the proportionality factor, which is a function of temperature and pressure only, being determined by the condition that at constant temperature and pressure a_B divided by the molality ratio $m_B/m^\ominus$ tends to 1 for infinite dilution; $m^\ominus$ is a standard molality, usually 1 mol/kg.	This quantity is dimensionless. $a_B = \lambda_B \cdot \lim_{\Sigma m_B \to 0} \frac{m_B/m^\ominus}{\lambda_B}$ The quantity $a_{c,B}$ similarly defined in terms of the concentration ratio $c_B/c^\ominus$ is also called : activity or relative activity of solute substance B; $c^\ominus$ is a standard concentration, usually 1 mol/dm³. $a_{c,B} = \lambda_B \cdot \lim_{\Sigma c_B \to 0} \frac{c_B/c^\ominus}{\lambda_B}$ The subscript c in $a_{c,B}$ is often omitted.

8. Physical chemistry and molecular physics (continued)

Units
8-17.a . . . 8-20.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-17.a	joule per mole	J/mol			
8-19.a	pascal	Pa			1 atm = 101 325 Pa (exactly). The use of this unit is deprecated. This does not imply that the use of 101 325 Pa as a reference pressure is deprecated.
8-20.a	pascal	Pa			See 8-19.a.

Quantities
8-24.1 . . . 8-28.1

8. Physical chemistry and molecular physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
8-24.1 (8-22.1)	activity coefficient of solute substance B (especially in a dilute liquid solution)	γ_B	For a solute substance in a solution $\gamma_B = \dfrac{a_B}{m_B/m^\ominus}$	These quantities are dimensionless. The name activity coefficient of solute substance B is also used for the quantity y_B defined as $y_B = \dfrac{a_{c,B}}{c_B/c^\ominus}$ See item 8-23.1. The name "activity factor" would be more systematic.
8-24.2 (—)	standard absolute activity of solute substance B (especially in a dilute liquid solution)	$\lambda_B^\ominus$	For a solute substance B in a solution $\lambda_B^\ominus = \lim_{\Sigma m_B \to 0} \{\lambda_B (p^\ominus) m^\ominus / m_B\}$	This quantity is a function only of temperature.
8-25.1 (—)	activity of solvent substance A, relative activity of solvent substance A (especially in a dilute liquid solution)	a_A	For the solvent substance A in a solution, a_A is equal to the ratio of the absolute activity λ_A to that, λ_A^*, of the pure solvent substance at the same temperature and pressure.	These quantities are dimensionless. $a_A = \lambda_A / \lambda_A^*$
8-25.2 (—)	osmotic coefficient of the solvent substance A (especially in a dilute liquid solution)	φ	$\varphi = -(M_A \Sigma m_B)^{-1} \ln a_A$ where M_A is the molar mass of the solvent substance A.	The name "osmotic factor" would be more systematic.
8-25.3 (—)	standard absolute activity of solvent substance A (especially in a dilute liquid solution)	$\lambda_A^\ominus$	For the solvent substance A in a solution $\lambda_A^\ominus = \lambda_A^* (p^\ominus)$.	This quantity is a function only of temperature.
8-26.1 (8-24.1)	osmotic pressure	Π	The excess pressure required to maintain osmotic equilibrium between a solution and the pure solvent separated by a membrane permeable only to the solvent.	
8-27.1 (8-25.1)	stoichiometric number of substance B	ν_B	The numbers or simple fractions occurring in the expression for a chemical reaction : $0 = \Sigma \nu_B B$, where the symbol B indicates the molecules or atoms involved in the reaction.	This quantity is dimensionless. In the present formulation the stoichiometric numbers for reactants are negative and those for products are positive.
8-28.1 (8-26.1)	affinity (of a chemical reaction)	A	$A = -\Sigma \nu_B \mu_B$	If A is used as symbol for Helmholtz free energy, an italic bold face $\boldsymbol{A}$ or sans serif A is often used as symbol for affinity.

8. Physical chemistry and molecular physics (continued)

Units
8-26.a . . . 8-28.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-26.a	pascal	Pa			
8-28.a	joule per mole	J/mol			

Quantities
8-29.1 . . . 8-33.2

8. Physical chemistry and molecular physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
8-29.1 (8-27.1)	standard equilibrium constant	$K^\ominus$	For a chemical reaction, $K^\ominus$ is the product $\Pi_B(\lambda_B^\ominus)^{-\nu_B}$.	This quantity is dimensionless. This quantity is a function only of temperature. Other "equilibrium constants" depend on temperature and pressure. Examples : $K_f = \Pi_B(f_B)^{\nu_B}$ for gases, $K_{xf} = \Pi_B(x_B f_B)^{\nu_B}$ for mixtures, and $K_a = \Pi_B(a_B)^{\nu_B}$ for solutions. Others depend on temperature, pressure, and composition. Examples : $K_p = \Pi_B(p_B)^{\nu_B}$ for gases, $K_x = \Pi_B(x_B)^{\nu_B}$ for mixtures, and $K_m = \Pi_B(m_B)^{\nu_B}$ or $K_c = \Pi_B(c_B)^{\nu_B}$ for solutions. Some of them (K_f, K_p, K_m, K_c) are not always dimensionless. Similarly, the standard "solubility product" of a solution saturated by an electrolyte C_xA_y is the dimensionless quantity $K^\ominus = x^x y^y (my\gamma/m^\ominus)^{x+y}$, where m is the molality and γ the activity coefficient of C_xA_y in the solution and $m^\ominus$ is a standard molality, usually 1 mol/kg.
8-30.1 (8-28.1)	mass of molecule	m		$m = M_r m_u$ where m_u is the (unified) atomic mass constant, see ISO 31/9.
8-31.1 (8-29.1)	electric dipole moment of molecule	p, μ	The electric dipole moment is a vector quantity, the vector product of which with the electric field strength is equal to the torque.	
8-32.1 (8-30.1)	electric polarizability of a molecule	α	Induced electric dipole moment divided by electric field strength.	γ is also used.
8-33.1 (–)	microcanonical partition function	Ω	$\Omega = \Sigma_r 1$ where the sum is over all quantum states consistent with given energy, volume, external fields, and content.	These quantities are dimensionless. $S = k \ln \Omega$.
8-33.2 (8-31.1)	canonical partition function	Q, Z	$Z = \Sigma_r \exp(-E_r/kT)$ where the sum is over all quantum states consistent with given volume, external fields, and content, and where E_r is the energy of the rth quantum state.	For k see 8-36.1. $A = -kT \ln Z$, where A is the Helmholtz free energy.

8. Physical chemistry and molecular physics (continued)

Units
8-30.a . . . 8-32.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-30.a	kilogram	kg			For (unified) atomic mass unit, $1\ u = m(^{12}C)/12$; see ISO 31/9.
8-31.a	coulomb metre	C·m			The gaussian CGS unit of electric dipole moment of a molecule corresponds to $3{,}335\,63 \times 10^{-12}$ C·m.
8-32.a	coulomb metre squared per volt	C·m²/V			The gaussian CGS unit of polarizability of a molecule equal to 1 cm³ corresponds to $1{,}112\,65 \times 10^{-16}$ C·m²/V.

8. Physical chemistry and molecular physics (continued)

Quantities
8-33.3 . . . 8-43.1

Item No.	Quantity	Symbol	Definition	Remarks
8-33.3	grand-canonical partition function, grand partition function	Ξ	$\Xi = \sum_{N_A, N_B, \ldots} Z(N_A, N_B, \ldots) \cdot \lambda_A^{N_A} \cdot \lambda_B^{N_B} \ldots$ where $Z(N_A, N_B, \ldots)$ is the canonical partition function for given numbers of particles A, B, . . ., and λ_A, λ_B, . . ., are the absolute activities of particles A, B, . . .	$A - \Sigma \mu_B n_B = -kT \ln \Xi$ where μ_B is the chemical potential of B.
8-33.4	molecular partition function, partition function of a molecule	q	$q = \Sigma_i \exp(-\varepsilon_i/kT)$ where ε_i is the energy of the ith allowed quantum state of the molecule consistent with given volume and external fields.	
8-34.1 (8-32.1)	statistical weight	g	Multiplicity of quantum energy level.	This quantity is dimensionless.
8-35.1 (8-33.1)	molar gas constant	R	The universal constant of proportionality in the ideal gas law : $pV_m = RT$	R = (8,314 41 ± 0,000 26) J/(mol·K) [1]
8-36.1 (8-34.1)	Boltzmann constant	k	$k = R/N_A$	k = (1,380 662 ± 0,000 044) × 10^{-23} J/K [1] β is used for $1/kT$, where T is the thermodynamic temperature.
8-37.1 (8-35.1)	mean free path	l, λ	For a molecule, the average distance between two successive collisions.	
8-38.1 8-36.1	diffusion coefficient	D	$C_B \langle v_B \rangle = -D \operatorname{grad} C_B$ where C_B is the local molecular concentration of substance B in the mixture and $\langle v_B \rangle$ is the local average velocity of the molecules B.	
8-39.1 (8-37.1)	thermal diffusion ratio	k_T	In the stationary state of a binary mixture in which thermal diffusion occurs : $\operatorname{grad} x_B = -(k_T/T) \operatorname{grad} T$ where x_B is the local mole fraction of the heavier substance B and T is the local temperature.	These quantities are dimensionless.
8-39.2 (8-37.2)	thermal diffusion factor	α_T	$\alpha_T = k_T/x_A x_B$ where x_A and x_B are the local mole fractions of the two substances.	
8-40.1 (8-38.1)	thermal diffusion coefficient	D_T	$D_T = k_T \cdot D$	
8-41.1 (8-39.1)	proton number	Z	The number of protons in an atomic nucleus.	This quantity is dimensionless. The atomic number in the Periodic Table is equal to the proton number.
8-42.1 (8-40.1)	elementary charge	e	The electric charge of a proton.	The electric charge of an electron is equal to $-e$. e = (1,602 189 2 ± 0,000 004 6) × 10^{-19} C [1]
8-43.1 (8-41.1)	charge number of ion	z	The ratio of the charge of the ion to the elementary charge.	This quantity is dimensionless. This quantity is negative for a negative ion.

[1] CODATA Bulletin 11 (1973).

8. Physical chemistry and molecular physics (continued)

Units
8-35.a . . . 8-42.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-35.a	joule per mole kelvin	J/(mol·K)			
8-36.a	joule per kelvin	J/K			
8-37.a	metre	m			
8-38.a	square metre per second	m^2/s			
8-40.a	square metre per second	m^2/s			
8-42.a	coulomb	C			

8. Physical chemistry and molecular physics (concluded)

Quantities
8-44.1 . . . 8-49.1

Item No.	Quantity	Symbol	Definition	Remarks
8-44.1 (8-42.1)	Faraday constant	F	$F = N_A e$	$F = (9{,}648\,456 \pm 0{,}000\,027) \times 10^4$ C/mol [1]
8-45.1 (8-43.1)	ionic strength	I	The ionic strength of a solution is defined as $I = \frac{1}{2} \Sigma z_i^2 m_i$ where the summation is carried out over all ions with molalities m_i.	
8-46.1 (8-44.1)	degree of dissociation	α	The ratio of the number of dissociated molecules to the total number of molecules.	This quantity is dimensionless. An alternative name for this quantity is "dissociation fraction".
8-47.1 (8-45.1)	electrolytic conductivity	κ, σ	The electrolytic current density divided by the electric field strength.	
8-48.1 (8-46.1)	molar conductivity	Λ_m	Conductivity divided by concentration.	
8-49.1 (8-47.1)	transport number of ionic substance B, current fraction of ionic substance B	t_B	The ratio of the current carried by ionic substance B to the total current.	This quantity is dimensionless.

(1) CODATA Bulletin 11 (1973).

8. Physical chemistry and molecular physics (concluded)

Units
8-44.a . . . 8-48.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
8-44.a	coulomb per mole	C/mol			
8-45.a	mole per kilogram	mol/kg			
8-47.a	siemens per metre	S/m			1 S = 1 Ω^{-1}
8-48.a	siemens square metre per mole	S·m²/mol			

Annex A[1]

Names and symbols of the chemical elements[2]

Atomic number	Name	Symbol	Atomic number	Name	Symbol
1	hydrogen	H	52	tellurium	Te
2	helium	He	53	iodine	I
3	lithium	Li	54	xenon	Xe
4	beryllium	Be	55	caesium	Cs
5	boron	B	56	barium	Ba
6	carbon	C	57	lanthanum	La
7	nitrogen	N	58	cerium	Ce
8	oxygen	O	59	praseodymium	Pr
9	fluorine	F	60	neodymium	Nd
10	neon	Ne	61	promethium	Pm
11	sodium, (natrium)	Na	62	samarium	Sm
12	magnesium	Mg	63	europium	Eu
13	aluminium	Al	64	gadolinium	Gd
14	silicon	Si	65	terbium	Tb
15	phosphorus	P	66	dysprosium	Dy
16	sulfur	S	67	holmium	Ho
17	chlorine	Cl	68	erbium	Er
18	argon	Ar	69	thulium	Tm
19	potassium, (kalium)	K	70	ytterbium	Yb
20	calcium	Ca	71	lutetium	Lu
21	scandium	Sc	72	hafnium	Hf
22	titanium	Ti	73	tantalum	Ta
23	vanadium	V	74	tungsten, (wolfram)	W
24	chromium	Cr	75	rhenium	Re
25	manganese	Mn	76	osmium	Os
26	iron	Fe	77	iridium	Ir
27	cobalt	Co	78	platinum	Pt
28	nickel	Ni	79	gold	Au
29	copper	Cu	80	mercury	Hg
30	zinc	Zn	81	thallium	Tl
31	gallium	Ga	82	lead	Pb
32	germanium	Ge	83	bismuth	Bi
33	arsenic	As	84	polonium	Po
34	selenium	Se	85	astatine	At
35	bromine	Br	86	radon	Rn
36	krypton	Kr	87	francium	Fr
37	rubidium	Rb	88	radium	Ra
38	strontium	Sr	89	actinium	Ac
39	yttrium	Y	90	thorium	Th
40	zirconium	Zr	91	protactinium	Pa
41	niobium	Nb	92	uranium	U
42	molybdenum	Mo	93	neptunium	Np
43	technetium	Tc	94	plutonium	Pu
44	ruthenium	Ru	95	americium	Am
45	rhodium	Rh	96	curium	Cm
46	palladium	Pd	97	berkelium	Bk
47	silver	Ag	98	californium	Cf
48	cadmium	Cd	99	einsteinium	Es
49	indium	In	100	fermium	Fm
50	tin	Sn	101	mendelevium	Md
51	antimony, (stibium)	Sb	102	nobelium	No
			103	lawrencium	Lr

IUPAC has approved a systematic nomenclature based on representating the digits of the proton number by syllables, for example unnilquadium (symbol : Unq) for element 104, for use as alternatives to special names for elements above 100, see *Pure and Applied Chemistry* 1979, **51**, 381.

(1) Annex A is an integral part of this standard.

(2) Quoted from : Atomic weights of the elements 1977, *Pure and Applied Chemistry* 1979, **51**, 405.

Annex B[1]

Symbols for chemical elements and nuclides

Symbols for chemical elements should be written in roman (upright) type. The symbol is not followed by a full stop.

Examples : H He C Ca

The attached subscripts or superscripts specifying a nuclide or molecule should have the following meanings and positions :

The nucleon number (mass number) of a nuclide is shown as a left superscript, for example

^{14}N

The number of atoms of a nuclide in a molecule is shown in the right subscript position, for example

$^{14}N_2$

The proton number may be indicated in the left subscript position, for example

$_{64}Gd$

If necessary a state of ionization or an excited state may be indicated in the right superscript position.

Examples :

State of ionization : Na^+, PO_4^{3-}

Electronic excited state : He^*, NO^*

Nuclear excited state : $^{110}Ag^*$ or $^{110}Ag^m$

Annex C[2]

pH

pH is defined operationally. For a solution X the electromotive force E_X of the galvanic cell :

reference electrode | concentrated solution of KCl | solution X | H_2 | Pt

is measured, and likewise the electromotive force E_S of a galvanic cell that differs only by the replacement of the solution X of unknown pH(X) by a solution S of standard pH(S). Then

$$pH(X) = pH(S) + (E_S - E_X)F/(RT \ln 10).$$

Thus defined, pH is dimensionless.

Values of pH(S) for several standard solutions are listed in the IUPAC Manual of Symbols and Terminology for Physicochemical Quantities and Units (1979).

pH has no fundamental meaning; the definition is a practical one. However, in the restricted range of dilute aqueous solutions having amount-of-substance concentrations less than 0,1 mol/dm^3 and being neither strongly acidic nor strongly alkaline ($2 < pH < 12$) the definition is such that

$$pH = -\log_{10}[c(H^+)\gamma_1/(\text{mol}\cdot\text{dm}^{-3})] \pm 0{,}02$$

where $c(H^+)$ denotes the amount-of-substance concentration of hydrogen ion H^+ and γ_1 denotes the activity coefficient of a typical uni-univalent electrolyte in the solution.

(1) Annex B is an integral part of this standard.

(2) Annex C is an integral part of this standard.

Quantities and units of atomic and nuclear physics

Introduction

This document, containing a table of *quantities and units of atomic and nuclear physics*, is part 9 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When a preferred symbol and a reserve symbol are given, the reserve symbol is in parentheses.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also ISO 31/0.

(1) When two types of sloping letters exist (for example as with θ; ϑ; φ; ϕ; g; g) only one of these is given. This does not mean that the other is not equally acceptable.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicity mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. These annexes are not integral parts of the standards. They are arranged in three groups :

1) *Units of the CGS system with special names*

It is generally preferable not to use the special names and symbols of CGS units together with SI units.

2) *Units based on the foot, pound and second and some other units*

3) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference of Weights and Measures has classified the SI units radian and steradian as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.[1]

In ISO 31, plane angle and solid angle are treated as derived quantities (see also ISO 31/0). In ISO 31, they are defined as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[2]

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits, and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

Special remarks

The fundamental physical constants given in this document are either quoted in or calculated from the consistent values of the fundamental physical constants published in CODATA Bulletin 11, 1973.

For some of the "electrical" quantities, equations founded on three base quantities, in particular equations of the Gaussian system, are given in Annex D, together with the numerical values of certain atomic constants expressed in the units of the Gaussian CGS system. For further details, see the introduction to ISO 31/5.

The names and symbols of the chemical elements are given in annex A.

The names and symbols for nuclides of the radioactive series are given in annex C.

In this standard, annexes A and B are integral parts of the standard. Annexes C, D and E are not integral parts of the standard.

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

(2) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

9. Atomic and nuclear physics

Quantities
9-1.1 . . . 9-7.1

Item No.	Quantity	Symbol	Definition	Remarks
9-1.1	proton number, atomic number	Z	Number of protons in an atomic nucleus.	This quantity is dimensionless. A nuclide is a species of atoms with specified numbers of protons and neutrons. Nuclides with the same value of Z are called isotopes. The atomic number in the periodic table is equal to the proton number. See also annex B.
9-2.1	neutron number	N	Number of neutrons in an atomic nucleus.	This quantity is dimensionless. Nuclides with the same value of N are called isotones. $N - Z$ is called the neutron excess number.
9-3.1	nucleon number, mass number	A	Number of nucleons in an atomic nucleus.	This quantity is dimensionless. $A \approx Z + N$ Nuclides with the same value of A are called isobars. See also annex B.
9-4.1	mass of atom (of a nuclide X), nuclidic mass	m_a, m(X)	Rest mass of a neutral atom in the ground state.	For hydrogen ^{1}H $m(^1\mathrm{H}) = (1{,}673\,559\,4 \pm 0{,}000\,008\,6) \times 10^{-27}$ kg $= (1{,}007\,825\,036 \pm 0{,}000\,000\,011)$ u
9-4.2	(unified) atomic mass constant	m_u	1/12 of the rest mass of a neutral atom of the nuclide ^{12}C in the ground state.	$m_u = (1{,}660\,565\,5 \pm 0{,}000\,008\,6) \times 10^{-27}$ kg $= 1$ u $\frac{m_a}{m_u}$ is called relative nuclidic mass.
9-5.1	(rest) mass of electron	m_e		For a particle with rest mass m the quantity mc^2 is called its rest energy. $m_e = (0{,}910\,953\,4 \pm 0{,}000\,004\,7) \times 10^{-30}$ kg $= (5{,}485\,802\,6 \pm 0{,}000\,002\,1) \times 10^{-4}$ u
9-5.2	(rest) mass of proton	m_p		$m_p = (1{,}672\,648\,5 \pm 0{,}000\,008\,6) \times 10^{-27}$ kg $= (1{,}007\,276\,470 \pm 0{,}000\,000\,011)$ u
9-5.3	(rest) mass of neutron	m_n		$m_n = (1{,}674\,954\,3 \pm 0{,}000\,008\,6) \times 10^{-27}$ kg $= (1{,}008\,665\,012 \pm 0{,}000\,000\,037)$ u
9-6.1	elementary charge	e	The electric charge of a proton.	The electric charge of an electron is equal to $(-e)$. $e = (1{,}602\,189\,2 \pm 0{,}000\,004\,6) \times 10^{-19}$ C
9-7.1	Planck constant	h	The elementary quantum of action.	$h = (6{,}626\,176 \pm 0{,}000\,036) \times 10^{-34}$ J.s $\hbar = h/2\pi$ $= (1{,}054\,588\,7 \pm 0{,}000\,005\,7) \times 10^{-34}$ J.s

9. Atomic and nuclear physics

Units
9-4.a . . . 9-7.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
9-4.a	kilogram	kg			
9-4.b	(unified) atomic mass unit	u	1 (unified) atomic mass unit is equal to 1/12 of the rest mass of a neutral atom of the nuclide ^{12}C in the ground state.	1 u = 1,660 565 5 × 10^{-27} kg	
9.5.a	kilogram	kg			
9-5.b	(unified) atomic mass unit	u		1 u = 1,660 565 5 × 10^{-27} kg	
9-6.a	coulomb	C			
9-7.a	joule second	J.s			

Quantities
9-8.1 . . . 9-16.1

9. Atomic and nuclear physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
9-8.1	Bohr radius	a_0	$a_0 = 4\pi\varepsilon_0\hbar^2/m_e e^2$	a_0 = (0,529 177 06 ± 0,000 000 44) × 10^{-10} m
9-9.1	Rydberg constant	R_∞	$R_\infty = \dfrac{e^2}{8\pi\varepsilon_0 a_0 hc}$	R_∞ = (1,097 373 177 ± 0,000 000 083) × 10^7 m^{-1} For hydrogen ^1H $R_H = R_\infty/(1 + m_e/m_p)$ The quantity $R_\infty \cdot hc$ is called the Rydberg energy (Ry).
9-10.1 (—)	Hartree energy	E_h	$E_h = e^2/4\pi\varepsilon_0 a_0 = 2R_\infty \cdot hc$	E_h = 4,359 81 × 10^{-18} J
9-11.1 (9-10.1)	magnetic moment of particle or nucleus	μ	Expectation value of the component of the electromagnetic moment in the direction of the magnetic field in the quantum state with maximum magnetic quantum number.	The energy in a magnetic field with magnetic flux density B, in the quantum state with maximum magnetic quantum number, in vacuo, is equal to $-\mu B$.
9-11.2 (9-10.2)	Bohr magneton	μ_B	$\mu_B = e\hbar/2m_e$	μ_B = (9,274 078 ± 0,000 036) × 10^{-24} A·m^2
9-11.3 (9-10.3)	nuclear magneton	μ_N	$\mu_N = e\hbar/2m_p = (m_e/m_p)\mu_B$	μ_N = (5,050 824 ± 0,000 020) × 10^{-27} A·m^2
9-12.1 (9-11.1)	gyromagnetic coefficient, (gyromagnetic ratio)	γ	$\gamma = \mu/J\hbar$ where J is the angular momentum quantum number.	The gyromagnetic coefficient of the proton is indicated by γ_p. γ_p = (2,675 198 7 ± 0,000 007 5) × 10^8 A·m^2/J·s.
9-13.1 (9-12.1)	g-factor of atom or electron	g	$\gamma = -g\dfrac{\mu_B}{\hbar} = -g\dfrac{e}{2m_e}$	These quantities are dimensionless. They are also called g-values.
9-13.2 (9-12.2)	g-factor of nucleus or nuclear particle	g	$\gamma = g\dfrac{\mu_N}{\hbar} = g\dfrac{e}{2m_p}$	
9-14.1 (9-13.1)	Larmor angular frequency, Larmor circular frequency	ω_L	$\omega_L = \dfrac{e}{2m_e}B$	$\nu_L = \omega_L/2\pi$ is called the Larmor frequency.
9-14.2 (9-13.2)	nuclear precession angular frequency, nuclear precession circular frequency	ω_N	$\omega_N = \gamma B$ where B is the magnetic flux density.	
9-15.1 (9-14.1)	cyclotron angular frequency, cyclotron circular frequency	ω_c	$\omega_c = \dfrac{q}{m}B$ where $\dfrac{q}{m}$ is the charge to mass ratio of the particle and B is the magnetic flux density.	$\nu_c = \omega_c/2\pi$ is called the cyclotron frequency.
9-16.1 (9-15.1)	nuclear quadrupole moment	Q	Expectation value of the quantity $(1/e)\int (3z^2 - r^2)\varrho(x,y,z)\,dx\,dy\,dz$ in the quantum state with the nuclear spin in the field (z) direction; $\varrho(x,y,z)$ is the nuclear charge density, e is the elementary charge.	The electric nuclear quadropole moment is eQ.

9. Atomic and nuclear physics (continued)

Units
9-8.a . . . 9-16.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
9-8.a	metre	m			
9-8.b	ångström	Å	1 Å = 10^{-10} m	1 Å = 10^{-10} m (exactly)	10 Å = 1 nm
9-9.a	reciprocal metre, metre to the power minus one	m^{-1}			
9-10.a	joule	J			
9-11.a	ampere square metre	A·m^2			
9-12.a	ampere square metre per joule second	A·m^2/(J·s)			1 A·m^2/(J·s) = 1 C/kg = 1 T^{-1}·s^{-1}
9-14.a	reciprocal second, second to the power minus one	s^{-1}			See the introduction.
9-14.b	radian per second	rad/s			
9-15.a	reciprocal second, second to the power minus one	s^{-1}			See the introduction.
9-15.b	radian per second	rad/s			
9-16.a	square metre	m^2			

9. Atomic and nuclear physics (continued)

Quantities
9-17.1 . . . 9-29.2

Item No.	Quantity	Symbol	Definition	Remarks
9-17.1 (9-16.1)	nuclear radius	R	The average radius of the volume in which the nuclear matter is included.	This quantity is not exactly defined. It is approximately given by $R = r_0 A^{1/3}$ where $r_0 \approx 1{,}2 \times 10^{-15}$ m.
9-18.1 (9-17.1)	orbital angular momemtum quantum number	l_i, L		This quantity is dimensionless. Usually l_i refers to a particle i; L is used for the whole system.
9-19.1 (9-18.1)	spin angular momentum quantum number	s_i, S		This quantity is dimensionless. Usually s_i refers to a particle i; S is used for the whole system.
9-20.1 (9-19.1)	total angular momentum quantum number	j_i, J		This quantity is dimensionless. Usually j_i refers to a particle i; J is used for the whole system.
9-21.1 (9-20.1)	nuclear spin quantum number	I		This quantity is dimensionless. In nuclear and particle physics J is often used.
9-22.1 (9-21.1)	hyperfine structure quantum number	F		This quantity is dimensionless.
9-23.1 (9-22.1)	principal quantum number	n		This quantity is dimensionless.
9-24.1 (9-23.1)	magnetic quantum number	m_i, M		This quantity is dimensionless. Usually m_i refers to a particle i; M is used for the whole system. Subscripts L, S, J, etc. as appropriate may be added to indicate the angular momentum involved.
9-25.1 (9-24.1)	fine-structure constant	α	$\alpha = e^2/4\pi\varepsilon_0\hbar c$	This quantity is dimensionless. α = (0,007 297 350 6 ± 0,000 000 006 0) $1/\alpha$ = 137,036 04 ± 0,000 11
9-26.1 (9-25.1)	electron radius	r_e	$r_e = e^2/4\pi\varepsilon_0 m_e c^2$	r_e = (2,817 938 0 ± 0,000 007 0) $\times 10^{-15}$ m.
9-27.1 (9-26.1)	Compton wavelength	λ_C	$\lambda_C = 2\pi\hbar/mc = h/mc$ where m is the rest mass of the particle.	For the proton, $\lambda_{C,p}$ = (1,321 409 9 ± 0,000 002 2) $\times 10^{-15}$ m. For the neutron, $\lambda_{C,n}$ = (1,319 590 9 ± 0,000 002 2) $\times 10^{-15}$ m.
9-28.1 (9-27.1)	mass excess	Δ	$\Delta = m_a - Am_u$	If the binding energy of the atomic electrons is neglected, Bc^2 is equal to the binding energy of the nucleus.
9-28.2 (9-27.2)	mass defect	B	$B = Zm(^1\mathrm{H}) + Nm_n - m_a$	
9-29.1 (9-28.1)	relative mass excess	Δ_r	$\Delta_r = \Delta/m_u$	These quantities are dimensionless.
9-29.2 (9-28.2)	relative mass defect	B_r	$B_r = B/m_u$	

9. Atomic and nuclear physics (continued)

Units
9-17.a . . . 9-28.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
9-17.a	metre	m			The quantity 9-17.1 is usually expressed in femtometres. 1 fm = 10^{-15} m
9-26.a	metre	m			
9-27.a	metre	m			
9-28.a	kilogram	kg			
9-28.b	(unified) atomic mass unit	u		1 u = 1,660 565 5 $\times 10^{-27}$ kg	The quantities 9-28 are usually expressed in (unified) atomic mass units.

Quantities
9-30.1 . . . 9-40.1

9. Atomic and nuclear physics (concluded)

Item No.	Quantity	Symbol	Definition	Remarks
9-30.1 (9-29.1)	packing fraction	f	$f = \Delta_t/A$	These quantities are dimensionless.
9-30.2 (9-29.2)	binding fraction	b	$b = B_t/A$	
9-31.1 (9-30.1)	mean life	τ	For exponential decay, the average time required to reduce the number N of atoms or nuclei in a specified state to N/e.	
9-32.1 (9-31.1)	level width	Γ	$\Gamma = \frac{\hbar}{\tau}$	
9-33.1 (9-32.1)	activity	A	The average number of spontaneous nuclear transitions from a particular energy state occurring in an amount of a radionuclide in a small time interval divided by that interval.	$A = -\mathrm{d}N/\mathrm{d}t$ For exponential decay, $A = \lambda N$. Here λ is the decay constant, see 9-35.1.
9-34.1 (9-33.1)	specific activity in a sample	a	The activity divided by the total mass of the sample.	
9-35.1 (9-34.1)	decay constant, disintegration constant	λ	The decay constant is the probability of decay in a small time interval, divided by that interval.	For exponential decay, $\mathrm{d}N/\mathrm{d}t = -\lambda N$ where N is the number of radioactive atoms at time t, and $\lambda = 1/\tau$.
9-36.1 (9-35.1)	half-life	$T_{1/2}$	For exponential decay, the average time required for the decay of one half of the atoms of a sample of a radioactive nuclide.	$T_{1/2} = (\ln 2)/\lambda$ $= \tau \ln 2$
9-37.1 (9-36.1)	alpha disintegration energy	Q_α	The sum of the kinetic energy of the α particle produced in the disintegration process and the recoil energy of the product atom in the reference frame in which the emitting nucleus is at rest before its disintegration.	The ground state alpha disintegration energy, $Q_{\alpha,0}$, includes also the energy of possible gamma radiation.
9-38.1 (9-37.1)	maximum beta particle energy	E_β	The maximum energy of the energy spectrum in a beta disintegration process.	
9-39.1 (9-38.1)	beta disintegration energy	Q_β	The sum of the maximum beta particle energy E_β and the recoil energy of the produced atom in the reference frame in which the emitting nucleus is at rest before its disintegration.	For emitters of positive electrons, the energy for the production of an electron pair has to be added to the sum mentioned in the definition. The ground state beta-disintegration energy, $Q_{\beta,0}$, includes also the energy of possible gamma radiation.
9-40.1 (9-39.1)	internal conversion factor	α	The ratio of the number of internal conversion electrons to the number of gamma quanta emitted by the atom in a given transition.	This quantity is dimensionless. The quantity $\alpha/(\alpha + 1)$ is also used and may be called internal conversion fraction. Partial conversion factors referring to various electron shells K, L, ... are indicated as α_K, α_L, ... α_K/α_L is called the K to L internal conversion ratio.

9. Atomic and nuclear physics (concluded)

Units
9-31.a . . . 9-39.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
9-31.a	second	s			
9-32.a	joule	J			
9-32.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	
9-33.a	becquerel	Bq	1 Bq = 1 s^{-1}		Becquerel is a special name for second to the power minus one to be used as SI unit of activity.
9-33.b	curie	Ci	1 Ci = 3,7 × 10^{10} Bq	1 Ci = 3,7 × 10^{10} Bq (exactly)	
9-34.a	becquerel per kilogram	Bq/kg			
9-34.b	curie per kilogram	Ci/kg			
9-35.a	reciprocal second, second to the power minus one	s^{-1}			
9-36.a	second	s			
9-37.a	joule	J			
9-37.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	The quantity 9-37.1 is usually expressed in electronvolts.
9-38.a	joule	J			
9-38.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	The quantity 9-38.1 is usually expressed in electronvolts.
9-39.a	joule	J			
9-39.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	The quantity 9-39.1 is usually expressed in electronvolts.

Annex A[1]

Names and symbols of the chemical elements[2]

Atomic number	Name	Symbol	Atomic number	Name	Symbol
1	hydrogen	H	52	tellurium	Te
2	helium	He	53	iodine	I
			54	xenon	Xe
3	lithium	Li			
4	beryllium	Be	55	caesium	Cs
5	boron	B	56	barium	Ba
6	carbon	C	57	lanthanum	La
7	nitrogen	N	58	cerium	Ce
8	oxygen	O	59	praseodymium	Pr
9	fluorine	F	60	neodymium	Nd
10	neon	Ne	61	promethium	Pm
			62	samarium	Sm
11	sodium, (natrium)	Na	63	europium	Eu
12	magnesium	Mg	64	gadolinium	Gd
13	aluminium	Al	65	terbium	Tb
14	silicon	Si	66	dysprosium	Dy
15	phosphorus	P	67	holmium	Ho
16	sulfur	S	68	erbium	Er
17	chlorine	Cl	69	thulium	Tm
18	argon	Ar	70	ytterbium	Yb
19	potassium, (kalium)	K	71	lutetium	Lu
20	calcium	Ca	72	hafnium	Hf
21	scandium	Sc	73	tantalum	Ta
22	titanium	Ti	74	tungsten, (wolfram)	W
23	vanadium	V	75	rhenium	Re
24	chromium	Cr	76	osmium	Os
25	manganese	Mn	77	iridium	Ir
26	iron	Fe	78	platinum	Pt
27	cobalt	Co	79	gold	Au
28	nickel	Ni	80	mercury	Hg
29	copper	Cu	81	thallium	Tl
30	zinc	Zn	82	lead	Pb
31	gallium	Ga	83	bismuth	Bi
32	germanium	Ge	84	polonium	Po
33	arsenic	As	85	astatine	At
34	selenium	Se	86	radon	Rn
35	bromine	Br			
36	krypton	Kr	87	francium	Fr
			88	radium	Ra
37	rubidium	Rb	89	actinium	Ac
38	strontium	Sr	90	thorium	Th
39	yttrium	Y	91	protactinium	Pa
40	zirconium	Zr	92	uranium	U
41	niobium	Nb	93	neptunium	Np
42	molybdenum	Mo	94	plutonium	Pu
43	technetium	Tc	95	americium	Am
44	ruthenium	Ru	96	curium	Cm
45	rhodium	Rh	97	berkelium	Bk
46	palladium	Pd	98	californium	Cf
47	silver	Ag	99	einsteinium	Es
48	cadmium	Cd	100	fermium	Fm
49	indium	In	101	mendelevium	Md
50	tin	Sn	102	nobelium	No
51	antimony, (stibium)	Sb	103	lawrencium	Lr

IUPAC has approved a systematic nomenclature based on representating the digits of the proton number by syllables, for example unnilquadium (symbol : Unq) for element 104, for use as alternatives to special names for elements above 100, see *Pure and Applied Chemistry*, 1979, 51, 381.

(1) Annex A is an integral part of this standard.

(2) Quoted from : Atomic weights of the elements 1977, *Pure and Applied Chemistry* 1979, 51, 405.

Annex B[1]

Symbols for chemical elements and nuclides

Symbols for chemical elements should be written in roman (upright) type. The symbol is not followed by a full stop.

Examples : H He C Ca

The attached subscripts or superscripts specifying a nuclide or molecule should have the following meanings and positions :

The nucleon number (mass number) of a nuclide is shown as a left superscript, for example

^{14}N

The number of atoms of a nuclide in a molecule is shown in the right subscript position, for example

$^{14}N_2$

The proton number may be indicated in the left subscript position, for example

$_{64}Gd$

If necessary a state of ionization or an excited state may be indicated in the right superscript position.

Examples :

State of ionization : Na^+, PO_4^{3-}

Electronic excited state : He^*, NO^*

Nuclear excited state : $^{110}Ag^*$ or $^{110}Ag^m$

Annex C[2]

Original names and symbols for nuclides of radioactive series

(4n + 2)-series (uranium series)			4n-series (thorium series)			(4n + 3)-series (actinium series)		
Name	Old symbol	Symbol of nuclide	Name	Old symbol	Symbol of nuclide	Name	Old symbol	Symbol of nuclide
uranium I	U I	^{238}U	thorium	Th	^{232}Th	actinouranium	Ac U	^{235}U
uranium X_1	U X_1	^{234}Th	mesothorium 1	$MsTh^1$	^{228}Ra	uranium Y	U Y	^{231}Th
uranium Z, uranium X_2	U Z, U X_2	^{234}Pa	mesothorium 2	$MsTh_2$	^{228}Ac	protoactinium	Pa	^{231}Pa
uranium II	U II	^{234}U	radiothorium	RdTh	^{228}Th	actinium	Ac	^{227}Ac
ionium	Io	^{230}Th	thorium X	Th X	^{224}Ra	radioactinium	RdAc	^{227}Th
radium	Ra	^{226}Ra	thoron	Tn	^{220}Rn	actinium K	Ac K	^{223}Fr
radon	Rn	^{222}Rn	thorium A	Th A	^{216}Po	actinium X	Ac X	^{223}Ra
radium A	Ra A	^{218}Po	thorium B	Th B	^{212}Pb	actinon	An	^{219}Rn
radium B	Ra B	^{214}Pb	thorium C	Th C	^{212}Bi	actinium A	Ac A	^{215}Po
radium C	Ra C	^{214}Bi	thorium C'	Th C'	^{212}Po	actinium B	Ac B	^{211}Pb
radium C'	Ra C'	^{214}Po	thorium C''	Th C''	^{208}Tl	actinium C	Ac C	^{211}Bi
radium C''	Ra C''	^{210}Tl	thorium D	Th D	^{208}Pb	actinium C'	Ac C'	^{211}Po
radium D	Ra D	^{210}Pb				actinium C''	Ac C''	^{207}Tl
radium E	Ra E	^{210}Bi				actinium D	Ac D	^{207}Pb
radium F (polonium)	Ra F	^{210}Po						
radium G	Ra G	^{206}Pb						

(1) Annex B is an integral part of this standard.

(2) Annex C is not an integral part of this standard.

Annex D[1]

Examples of relations in different systems of equations

Item No.	Subject	Rationalized system of equations with four base quantities	Gaussian system of equations with three base quantities
1	Bohr radius	$a_0 = 4\pi\varepsilon_0\hbar^2/m_e e^2$	$a_0 = \hbar^2/m_e e_s^2$
2	Rydberg constant	$R_\infty = m_e e^4/(4\pi)^3 \varepsilon_0^2 \hbar^3 c$	$R_\infty = m_e e_s^4/4\pi\hbar^3 c$
3	Bohr magneton	$\mu_B = e\hbar/2 m_e$	$\mu_{B,s} = e_s \hbar/2 m_e c$
4	nuclear magneton	$\mu_N = e\hbar/2 m_p$	$\mu_{N,s} = e_s \hbar/2 m_p c$
5	relation between gyromagnetic coefficient and g-factor of nucleus	$\gamma = g\,\mu_N/\hbar = g\,e/2 m_p$	$\gamma_s = g\,\mu_{N,s}/\hbar = g\,e_s/2 m_p c$
6	Larmor angular frequency	$\omega_L = (e/2 m_e) B$	$\omega_L = (e_s/2 m_e c) B_s$
7	cyclotron angular frequency (of electron)	$\omega_c = (e/m_e) B$	$\omega_c = (e_s/m_e c) B_s$
8	fine-structure constant	$\alpha = e^2/4\pi\varepsilon_0 \hbar c$	$\alpha = e_s^2/\hbar c$
9	electron radius	$r_e = e^2/4\pi\varepsilon_0 m_e c^2$	$r_e = e_s^2/m_e c^2$
10	Compton wavelength	$\lambda_C = \hbar/mc = 2\pi\hbar/mc$	$\lambda_C = \hbar/mc = 2\pi\hbar/mc$

Quantities occurring in the second column of equations which differ from the corresponding quantity in the first column of equations are provided with a suffix s (symmetric). The values of some of the quantities expressed in units of the Gaussian CGS system (see Introduction to ISO 31/5) are as follows :

$\mu_{B,s}$: 9,274 078 × 10^{-21} erg per gauss

$\mu_{N,s}$: 5,050 824 × 10^{-24} erg per gauss

$\gamma_{p,s}$: 2,675 198 7 × 10^4 reciprocal second reciprocal gauss, where $\gamma_{p,s}$ is the gyromagnetic coefficient γ_s of the proton.

Annex E[2]

Special names of units of the CGS system

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
9-7.1	Planck constant	9-7.A.a	erg second : erg·s	1 erg·s = 10^{-7} J·s (exactly)
9-32.1	level width	9-32.A.a	erg : erg	1 erg = 10^{-7} J (exactly)
9-37.1	alpha disintegration energy	9-37.A.a	erg : erg	
9-38.1	maximum beta particle energy	9-38.A.a	erg : erg	
9-39.1	beta disintegration energy	9-39.A.a	erg : erg	

NOTE — Annex E contains non-SI units of the CGS system with special names. These special names for quantities in this document should not be used together with SI units.

(1) Annex D is not an integral part of this standard.

(2) Annex E is not an integral part of this standard.

Quantities and units of nuclear reactions and ionizing radiations

Introduction

This document, containing a table of *quantities and units of nuclear reactions and ionizing radiations*, is part 10 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When a preferred symbol and a reserve symbol are given, the reserve symbol is in parentheses.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also ISO 31/0.

(1) When two types of sloping letters exist (for example as with θ; ϑ; φ; ϕ; g; g) only one of these is given; this does not mean that the other is not equally acceptable.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicity mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. These annexes are not integral parts of the standards. They are arranged in three groups :

a) *Units of the CGS system with special names*

It is generally preferable not to use the special names and symbols of CGS units together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference of Weights and Measures has classified the SI units radian and steradian as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.(1)

In ISO 31, plane angle and solid angle are treated as derived quantities (see also ISO 31/0). In ISO 31, they are defined as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements(2)

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits, and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

Special remarks

In this document the term "particle" includes particles without a rest mass as well as particles having a rest mass.

Distribution functions in terms of energy, velocity, solid angle etc. correspond to several quantities listed in this document. The subscripts E, v and Ω are used as part of the symbol to indicate that the quantity has the dimension of a derivative with respect to E, v and Ω respectively. In general these distribution functions are only mentioned in the remarks column; see for example 10-12.1, 10-29.1, 10-31.1 and 10-32.1.

In the case of cross sections, some of these distribution functions are given special names and are listed as separate items.

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

(2) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

Nuclear reactions and ionizing radiations

10. Nuclear reactions and ionizing radiations

Quantities
10-1.1 . . . 10-6.1

Item No.	Quantity	Symbol	Definition	Remarks
10-1.1	reaction energy	Q	In the nuclear reaction, the sum of the kinetic and photon energies of the reaction products minus the sum of the kinetic and photon energies of the reactant.	For exothermic nuclear reactions $Q > 0$. For endothermic nuclear reactions $Q < 0$. For beta disintegration, see ISO 31/9.
10-2.1	resonance energy	E_r, E_{res}	The kinetic energy of an incident particle, in the reference frame of the target, corresponding to a resonance in a nuclear reaction.	
10-3.1	cross section	σ	For a specified target entity and for a specified reaction or process produced by incident charged or uncharged particles of specified type and energy, the cross section is the quotient of the probability of this reaction or process for this target entity and the particle fluence of the incident particles.	The type of process is indicated with subscripts, e.g. absorption cross section σ_a, σ_A scattering cross section σ_s, σ_S fission cross section σ_f.
10-3.2	total cross section	σ_{tot}, σ_T	The sum of all cross sections corresponding to the various reactions or processes between incident particle and target particle.	In the case of a narrow unidirectional beam of incident particles, this is the effective cross section for the removal of an incident particle from the beam. See remark to 10-16.1.
10-4.1	angular cross section	σ_Ω	Cross section for ejecting or scattering a particle into an element of solid angle, divided by this element. $\sigma = \int \sigma_\Omega \, d\Omega$	The quantities 10-4.1, 10-5.1 and 10-6.1 are sometimes called differential cross sections. In accordance with conventions used in other parts of ISO 31 angular and spectral cross sections are indicated by the use of subscripts. The information about incoming and outgoing particles may be added between parentheses, e.g. $\sigma_{\Omega,E}$ $(n E_0, p E \theta)$ or $\sigma_{\Omega,E}$ $(n E_0; p)$ or $\sigma_{\Omega,E}$ $(n;p)$. The cross section for a process in which an incoming neutron of energy E_0 causes the ejection of a proton within the energy interval $(E, E + dE)$ and in the element of solid angle $d\Omega$, about the scattering angle θ is $\sigma_{\Omega,E}$ $(n E_0, p E \theta)$ $d\Omega \, dE$. Sometimes the incoming and outgoing particles are indicated by subscripts, in which case the subscripts Ω and/or E indicating the angular and/or spectral character could be placed in superscript position, e.g. $\sigma^{E,\theta}_{n,p}(E_0)$ or $\sigma^{E,\theta}_{n,p}$. If, however, the subscripts Ω and/or E are omitted completely from the cross section symbol, the angular and/or spectral character of the cross section then follows only from the occurrence of the variables θ and/or E for the outgoing particles between the parentheses, e.g. $\sigma_{n,p}$ $(E_0, E\ \theta)$ or $\sigma_{n,p}$ $(E\ \theta)$. These variables should then never be omitted.
10-5.1	spectral cross section	σ_E	Cross section for a process in which the energy of the ejected or scattered particle is in an element of energy, divided by this element. $\sigma = \int \sigma_E \, dE$	
10-6.1	spectral angular cross section	$\sigma_{\Omega,E}$	Cross section for ejecting or scattering a particle into an element of solid angle with energy in an element of energy, divided by the product of these two elements. $\sigma = \int\int \sigma_{\Omega,E} \, d\Omega \, dE$	

10. Nuclear reactions and ionizing radiations

Units
10-1.a . . . 10-6.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-1.a	joule	J			
10-1.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	See also ISO 31/3. The quantity 10-1.1 is usually expressed in electronvolts.
10-2.a	joule	J			
10-2.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	The quantity 10-2.1 is usually expressed in electronvolts.
10-3.a	square metre	m^2			
10-3.b	barn	b	1 b = 10^{-28} m^2	1 b = 10^{-28} m^2 (exactly)	
10-4.a	square metre per steradian	m^2/sr			
10-4.b	barn per steradian	b/sr		1 b/sr = 10^{-28} m^2/sr (exactly)	
10-5.a	square metre per joule	m^2/J			
10-5.b	barn per electronvolt	b/eV		1 b/eV = 6,241 46 × 10^{-10} m^2/J	
10-6.a	square metre per steradian joule	$m^2/(sr \cdot J)$			
10-6.b	barn per steradian electronvolt	b/(sr·eV)		1 b/(sr·eV) = 6,241 46 × 10^{-10} $m^2/(sr \cdot J)$	

10. Nuclear reactions and ionizing radiations (continued)

Quantities
10-7.1 . . . 10-17.1

Item No.	Quantity	Symbol	Definition	Remarks
10-7.1	macroscopic cross section, cross section density	Σ	The sum of the cross sections for a reaction or process of a specified type over all atoms in a given volume, divided by that volume.	$\Sigma = n_1\sigma_1 + \ldots + n_i\sigma_i + \ldots$ (n_i is the number density and σ_i is the cross section for atoms of type i). When the target particles of the medium are at rest $\Sigma = 1/l$, where l is the mean free path, see 10-39.1. See remark to 10-13.1.
10-7.2	total macroscopic cross section, total cross section density	Σ_{tot}, Σ_T	The sum of total cross sections for all atoms in a given volume, divided by that volume.	
10-8.1 (—)	particle fluence	Φ	At a given point in space, the number of particles incident on a small sphere in a time interval, divided by the cross-sectional area of that sphere.	Usually the word particle is replaced by the name of a specific particle, for example proton fluence.
10-9.1 (—)	particle fluence rate, particle flux density	φ	$\varphi = \frac{d\Phi}{dt}$	See also 10-31.1, where distribution functions are also included in the "Remarks" column.
10-10.1 (—)	energy fluence	Ψ	At a given point in space, the sum of the energies, exclusive of rest energy, of all the particles incident on a small sphere in a time interval, divided by the cross sectional area of that sphere.	
10-11.1 (—)	energy fluence rate, energy flux density	ψ	$\psi = \frac{d\Psi}{dt}$	
10-12.1 (10-10.1)	current density of particles	J, (S)	A vector quantity the integral of whose normal component over any surface is equal to the net number of particles passing through that surface in a small time interval divided by that interval.	S is recommended when there is a possibility of confusion with the symbol J for electric current density. For neutron current density the symbol J is generally used. The distribution functions in terms of speed and energy, J_v and J_E, are related to J by $J = \int J_v \, dv = \int J_E \, dE$
10-13.1 (10-11.1)	linear attenuation coefficient	μ, μ_l	$dJ/dx = -\mu J$ where J is the current density of a beam of particles parallel to the x-direction.	μ is equal to the total macroscopic cross section Σ_{tot} for removal of particles from the beam.
10-14.1 (10-13.1)	mass attenuation coefficient	μ/ϱ, μ_m	The linear attenuation coefficient divided by the mass density of the substance.	
10-15.1 (—)	molar attenuation coefficient	μ_c	$\mu_c = \mu/c$ where c is the amount-of-substance concentration.	
10-16.1 (10-12.1)	atomic attenuation coefficient	μ_a, μ_{at}	$\mu_a = \mu/n$ where n is the number density of atoms in the substance (see also 10-27.1).	μ_a is equal to the total cross section σ_{tot} for removal of particles from the beam.
10-17.1 (10-14.1)	half-thickness, half value thickness	$d_{1/2}$	The thickness of the attenuating layer that reduces the current density of a unidirectional beam to one-half of its initial value.	For exponential attenuation $d_{1/2} = (\ln 2)/\mu$. Other half value thicknesses, such as that for attenuation of absorbed dose rate, are also used.

10. Nuclear reactions and ionizing radiations (continued)

Units
10-7.a . . . 10-17.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-7.a	reciprocal metre, metre to the power minus one	m^{-1}			
10-8.a	reciprocal square metre, metre to the power minus two	m^{-2}			
10-9.a	reciprocal square metre reciprocal second, metre to the power minus two second to the power minus one	$m^{-2}.s^{-1}$			
10-10.a	joule per square metre	J/m^2			
10-11.a	watt per square metre	W/m^2			
10-12.a	reciprocal square metre reciprocal second, metre to the power minus two second to the power minus one	$m^{-2}.s^{-1}$			
10-13.a	reciprocal metre, metre to the power minus one	m^{-1}			
10-14.a	square metre per kilogram	m^2/kg			
10-15.a	square metre per mole	m^2/mol			
10-16.a	square metre	m^2			
10-17.a	metre	m			

Quantities
10-18.1 . . . 10-28.1

10. Nuclear reactions and ionizing radiation (continued)

Item No.	Quantity	Symbol	Definition	Remarks
10-18.1 (10-15.1)	total linear stopping power	S, S_l	For an ionizing charged particle of energy E moving in the x-direction $S = -\mathrm{d}E/\mathrm{d}x$	Also called stopping power. Both collision losses and radiation losses are included. The ratio of the total linear stopping power of a substance to that of a reference substance is called relative linear stopping power. See also 10-54.1.
10-19.1 (10-16.1)	total atomic stopping power	S_a	$S_a = S/n$ where n is the number density of atoms in the substance.	
10-20.1 (10-17.1)	total mass stopping power	S/ϱ, (S_m)	The total linear stopping power divided by the mass density of the substance.	The ratio of the total mass stopping power of a substance to that of a reference substance is called relative mass stopping power.
10-21.1 (10-19.1)	mean linear range	R, R_l	The distance that a particle penetrates in a given substance under specified conditions averaged over a group of particles having the same energy.	
10-22.1 (10-20.1)	mean mass range	R_ϱ, (R_m)	The mean linear range multiplied by the mass density of the substance.	
10-23.1 (10-21.1)	linear ionization by a particle	N_{il}	The number of elementary charges of one sign produced over an element of length of the path of an ionizing charged particle, divided by that element.	Ionization due to secondary ionizing particles etc. is included.
10-24.1 (10-22.1)	total ionization by a particle	N_i	The total number of elementary charges of one sign produced by an ionizing charged particle along its entire path.	This quantity is dimensionless. $N_i = \int N_{il}\,\mathrm{d}l$ See remark to 10-23.1.
10-25.1 (10-23.1)	average energy loss per ion pair formed, (average energy loss per elementary charge of one sign produced)	W_i	The initial kinetic energy of an ionizing charged particle, divided by the total ionization by that particle.	The quantity S_l/N_{il}, sometimes called average energy per ion pair formed, should not be confused with W_i.
10-26.1 (10-24.1)	mobility	μ	The average drift velocity imparted to a charged particle in a medium by an electric field, divided by the field strength.	
10-27.1 (10-25.1)	ion number density, ion density	n^+, n^-	The number of positive or negative ions in a volume element, divided by that element.	n is the general symbol for number density of particles.
10-28.1 (10-26.1)	recombination coefficient	α	Coefficient in the law of recombination $-\frac{\mathrm{d}n^+}{\mathrm{d}t} = -\frac{\mathrm{d}n^-}{\mathrm{d}t} = \alpha n^+ n^-$	

10. Nuclear reactions and ionizing radiations (continued)

Units
10-18.a . . . 10-28.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-18.a	joule per metre	J/m			
10-18.b	electronvolt per metre	eV/m		1 eV/m = 1,602 189 2 × 10^{-19} J/m	
10-19.a	joule square metre	J·m²			
10-19.b	electronvolt square metre	eV·m²		1 eV·m² = 1,602 189 2 × 10^{-19} J·m²	
10-20.a	joule square metre per kilogram	J·m²/kg			
10-20.b	electronvolt square metre per kilogram	eV·m²/kg		1 eV·m²/kg = 1,602 189 2 × 10^{-19} J·m²/kg	
10-21.a	metre	m			
10-22.a	kilogram per square metre	kg/m²			
10-23.a	reciprocal metre, metre to the power minus one	m^{-1}			
10-25.a	joule	J			
10-25.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	
10-26.a	square metre per volt second	m²/(V·s)			
10-27.a	reciprocal cubic metre, metre to the power minus three	m^{-3}			
10-28.a	cubic metre per second	m³/s			

Quantities
10-29.1 . . . 10-38.1

10. Nuclear reactions and ionizing radiations (continued)

Item No.	Quantity	Symbol	Definition	Remarks
10-29.1 (10-27.1)	neutron number density	n	The number of free neutrons in a volume element, divided by that element.	The distribution functions in terms of speed and energy n_v and n_E are related to n by $n = \int n_v \, dv = \int n_E \, dE$
10-30.1 (10-28.1)	neutron speed	v	The magnitude of the neutron velocity.	
10-31.1 (10-29.1)	neutron fluence rate, neutron flux density	φ	At a given point in space, the number of neutrons incident on a small sphere in a small time interval, divided by the cross sectional area of that sphere and by the time interval.	See also 10-8.1. The distribution functions in terms of speed and energy φ_v and φ_E are related to φ by $\varphi = \int \varphi_v \, dv = \int \varphi_E \, dE$. $\varphi_v = n_v v$ and $\varphi = n < v >$, where $< v >$ is the average neutron speed. φ is sometimes called neutron flux.
10-32.1 (10-30.1)	diffusion coefficient, diffusion coefficient for neutron number density	D, D_n	$J_x = - D_n \, \partial n / \partial x$ where J_x is the x-component of the neutron current density and n is the number density of neutrons.	The distribution function in terms of speed $J_{v,x}$ is related to J_x by $J_x = \int J_{v,x} \, dv$. See 10-12.1.
10-33.1 (10-31.1)	diffusion coefficient for neutron fluence rate, diffusion coefficient for neutron flux density	D_φ, (D)	$J_x = - D_\varphi \, \partial \varphi / \partial x$ where J_x is the x-component of the neutron current density and φ is the neutron fluence rate.	For neutrons of a given speed $J_{v,x} = - D_n(v) \, \partial n_v / \partial x = - D_\varphi(v) \, \partial \varphi_v / \partial x$ where $v D_\varphi(v) = D_n(v)$.
10-34.1 (10-32.1)	total neutron source density	S	The rate of production of neutrons in a volume element, divided by that element.	The distribution functions in terms of speed and energy S_v and S_E are related to S by $S = \int S_v \, dv = \int S_E \, dE$
10-35.1 (10-33.1)	slowing-down density	q	The number density of neutrons slowing down past a given energy value in a small time interval, divided by that interval.	
10-36.1 (10-34.1)	resonance escape probability	p	In an infinite medium, the probability that a neutron slowing down will traverse all or some specified portion of the range of resonance energies without being absorbed.	This quantity is dimensionless.
10-37.1 (10-35.1)	lethargy	u	The lethargy of a neutron of energy E is defined as $u = \ln (E_0 / E)$ where E_0 is a reference energy.	This quantity is dimensionless.
10-38.1 (10-36.1)	average logarithmic energy decrement	ξ	The average value of the increase in lethargy in elastic collisions between neutrons and nuclei whose kinetic energy is negligible compared with that of the neutrons.	This quantity is dimensionless.

10. Nuclear reactions and ionizing radiations (continued)

Units
10-29.a . . . 10-35.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-29.a	reciprocal cubic metre, metre to the power minus three	m^{-3}			
10-30.a	metre per second	m/s			
10-31.a	reciprocal second reciprocal square metre, second to the power minus one metre to the power minus two	$s^{-1} \cdot m^{-2}$			
10-32.a	square metre per second	m^2/s			
10-33.a	metre	m			
10-34.a	reciprocal second reciprocal cubic metre, second to the power minus one metre to the power minus three	$s^{-1} \cdot m^{-3}$			
10-35.a	reciprocal second reciprocal cubic metre, second to the power minus one metre to the power minus three	$s^{-1} \cdot m^{-3}$			

Quantities
10-39.1 . . . 10-45.1

10. Nuclear reactions and ionizing radiations (continued)

Item No.	Quantity	Symbol	Definition	Remarks
10-39.1 (10-37.1)	mean free path	l, λ	The average distance which particles travel between two successive specified reactions or processes.	See remark to 10-7.1.
10-40.1 (10-38.1)	slowing-down area	L_s^2, L_{sl}^2	In an infinite homogeneous medium, one sixth of the mean square distance between the source of a neutron and the point where the neutron reaches a given energy.	When the Fermi age theory is applicable this quantity is equal to the "Fermi age", τ.
10-40.2 (10-38.2)	diffusion area	L^2	In an infinite homogeneous medium, one sixth of the mean square distance between the point where a neutron enters a specified class and the point where it leaves this class.	
10-40.3 (10-38.3)	migration area	M^2	The sum of the slowing-down area from fission energy to thermal energy and the diffusion area for thermal neutrons.	
10-41.1 (10-39.1)	slowing-down length	L_s, L_{sl}	The square root of the slowing-down area.	
10-41.2 (10-39.2)	diffusion length	L	The square root of the diffusion area.	
10-41.3 (10-39.3)	migration length	M	The square root of the migration area.	
10-42.1 (10-40.1)	neutron yield per fission	ν	The average number of fission neutrons, both prompt and delayed, emitted per neutron fission.	These quantites are dimensionless. Also called ν-factor and η-factor respectively.
10-42.2 (10-40.2)	neutron yield per absorption	η	The average number of fission neutrons, both prompt and delayed, emitted per neutron absorbed in a fissionable nuclide or in a nuclear fuel, as specified.	η/ν is equal to the ratio of the macroscopic cross section for fission to that for absorption, both for neutrons in the fuel material.
10-43.1 (10-41.1)	fast fission factor	ε	In an infinite medium, the ratio of the mean number of neutrons produced by fissions due to neutrons of all energies, to the mean number of neutrons produced by thermal fissions only.	This quantity is dimensionless.
10-44.1 (10-42.1)	thermal utilization factor	f	In an infinite medium, the ratio of the number of thermal neutrons absorbed in a fissionable nuclide or in a nuclear fuel, as specified, to the total number of thermal neutrons absorbed.	This quantity is dimensionless.
10-45.1 (10-43.1)	non-leakage probability	Λ	The probability that a neutron will not escape from the reactor during the slowing-down process or while it diffuses as a thermal neutron.	This quantity is dimensionless.

10. Nuclear reactions and ionizing radiations (continued)

Units
10-39.a . . . 10-41.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-39.a	metre	m			
10-40.a	metre squared	m^2			
10-41.a	metre	m			

10. Nuclear reactions and ionizing radiations (continued)

Quantities
10-46.1 . . . 10-51.2

Item No.	Quantity	Symbol	Definition	Remarks
10-46.1 (10-44.1)	multiplication factor	k	The ratio of the total number of fission or fission dependent neutrons produced in a time interval to the total number of neutrons lost by absorption and leakage during the same interval.	These quantities are dimensionless.
10-46.2 (10-44.2)	infinite medium multiplication factor	k_∞	The multiplication factor for an infinite medium or for an infinite repeating lattice.	For a thermal reactor $k_\infty = \eta \varepsilon p f$
10-46.3 (10-44.3)	effective multiplication factor	k_{eff}	The multiplication factor for a finite medium.	
10-47.1 (10-45.1)	reactivity	ϱ	$\varrho = \dfrac{k_{\text{eff}} - 1}{k_{\text{eff}}}$	This quantity is dimensionless.
10-48.1 (10-46.1)	reactor time constant	T	The time required for the neutron fluence rate in a reactor to change by the factor e when the fluence rate is rising or falling exponentially.	Also called reactor period.
10-49.1 (10-47.1)	activity	A	The average number of spontaneous nuclear transitions from a particular energy state occurring in an amount of a radionuclide in a small time interval, divided by that interval.	$A = -\mathrm{d}N/\mathrm{d}t$ For exponential decay, $A = \lambda N$. Here λ is the decay constant, see ISO 31/9, 9-35.1.
10-50.1 (10-48.1)	energy imparted	ε	The energy imparted by ionizing radiation to the matter in a volume is the difference between the sum of the energies of all the directly ionizing (charged) and indirectly ionizing (uncharged) particles which have entered the volume and the sum of the energies of all those which have left it, minus the energy equivalent of any increase in rest mass that took place in nuclear or elementary particle reactions within the volume.	
10-50.2 (—)	mean energy imparted	$\bar{\varepsilon}$	The average of the energy imparted.	This quantity has sometimes been called integral absorbed dose.
10-51.1 (—)	specific energy imparted	z	For any ionizing radiation, the energy imparted to an element of irradiated matter divided by the mass of this element.	$\varepsilon = \int z \, \mathrm{d}m$
10-51.2 (10-49.1)	absorbed dose	D	For any ionizing radiation, the mean energy imparted to an element of irradiated matter divided by the mass of this element.	$\bar{\varepsilon} = \int D \, \mathrm{d}m$ where $\mathrm{d}m$ is an element of mass of the irradiated matter.

10. Nuclear reactions and ionizing radiations (continued)

Units
10-48.a . . . 10-51.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-48.a	second	s			
10-49.a	becquerel	Bq	1 Bq = 1 s^{-1}		Becquerel is a special name for second to the power minus one, to be used as SI unit of activity.
10-49.b	curie	Ci	1 Ci = 3,7 × 10^{10} Bq	1 Ci = 3,7 × 10^{10} Bq (exactly)	
10-50.a	joule	J			
10-51.a	gray	Gy	1 Gy = 1 J/kg		Gray is a special name for joule per kilogram to be used as SI unit for these quantities.
10-51.b	rad	rad	1 rad = 10^{-2} Gy		

Quantities
10-52.1 . . . 10.59.1

10. Nuclear reactions and ionizing radiations (concluded)

Item No.	Quantity	Symbol	Definition	Remarks
10-52.1 (—)	dose equivalent	H	The dose equivalent is the product of D, Q and N, at the point of interest in tissue, where D is the absorbed dose, Q is the quality factor and N is the product of any other modifying factors.	For Q and N, see ICRU Report 19, Supplement (Sept. 1973).
10-53.1 (10-50.1)	absorbed dose rate	$\dot{D}$	Absorbed dose in a small time interval divided by that interval.	$\dot{D} = \frac{dD}{dt}$
10-54.1 (10-51.1)	linear energy transfer	L	For an ionizing charged particle, the energy locally imparted to matter in traversing a small distance, divided by that distance.	This quantity is not completely defined unless the limits involved in the term "locally imparted energy" are specified; e.g. energy transfers in collisions below a specified maximum may be considered.
10-55.1 (10-52.1)	kerma	K	For indirectly ionizing (uncharged) particles, sum of the initial kinetic energies of all charged particles liberated in an element of matter, divided by the mass of that element.	The name kerma is derived from Kinetic Energy Released in MAtter.
10-56.1 (10-53.1)	kerma rate	$\dot{K}$	Kerma in a small time interval, divided by that interval.	$\dot{K} = \frac{dK}{dt}$
10-57.1 (10-54.1)	mass energy transfer coefficient	μ_{tr}/ϱ	For a beam of indirectly ionizing (uncharged) particles $\mu_{tr}/\varrho = \dot{K}/\psi$ where ψ is the energy fluence rate.	The quantity $\mu_{en}/\varrho = (\mu_{tr}/\varrho)(1 - G)$ where G is the fraction of the energy of the secondary charged particles that is lost to bremsstrahlung, is called mass energy absorption coefficient. See also 10-14.1.
10-58.1 (10-55.1)	exposure	X	For X- or gamma radiation, the total electric charge of the ions of one sign produced when all the electrons (negative and positive) liberated by photons in an element of air are stopped in air, divided by the mass of that element.	The ionization arising from the absorption of bremsstrahlung emitted by the secondary electrons liberated in the element is not included. This quantity should not be confused with the quantity light exposure, see ISO 31/6, 6-25.1.
10-59.1 (10-56.1)	exposure rate	$\dot{X}$	Exposure in a small time interval, divided by that interval.	$\dot{X} = \frac{dX}{dt}$

10. Nuclear reactions and ionizing radiations (concluded)

Units
10-52.a . . . 10-59.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
10-52.a	sievert	Sv	1 Sv = 1 J/kg		Sievert is a special name for joule per kilogram to be used as SI unit for dose equivalent.
10-52.b	rem	rem	1 rem = 10^{-2} Sv		Rem is a special name for 10^{-2} Sv.
10-53.a	gray per second	Gy/s	1 Gy/s = 1 W/kg		See remark to 10-51.a.
10-54.a	joule per metre	J/m			
10-54.b	electronvolt per metre	eV/m		1 eV/m = 1,602 189 2 × 10^{-19} J/m	
10-55.a	gray	Gy	1 Gy = 1 J/kg		See remark to 10-51.a.
10-56.a	gray per second	Gy/s	1 Gy/s = 1 W/kg		See remark to 10-51.a.
10-57.a	square metre per kilogram	m^2/kg			
10-58.a	coulomb per kilogram	C/kg			
10-58.b	röntgen	R	1 R = 2,58 × 10^{-4} C/kg	1 R = 2,58 × 10^{-4} C/kg (exactly)	The röntgen is a special unit for the quantity 10-58.1.
10-59.a	coulomb per kilogram second	C/(kg·s)	1 C/(kg·s) = 1 A/kg		
10-59.b	röntgen per second	R/s		1 R/s = 2,58 × 10^{-4} C/(kg·s) (exactly)	

Annex[1]

Special names of units of the CGS system

Quantity item No.	Quantity	Unit item No.	Name of unit with symbol	Definition and conversion factors
10-1.1	reaction energy	10-1.A.a	erg : erg	1 erg = 10^{-7} J (exactly)
10-2.1	resonance energy	10-2.A.a	erg : erg	1 erg = 10^{-7} J (exactly)
10-5.1	spectral cross section	10-5.A.a	square centimetre per erg : cm^2/erg	1 cm^2/erg = 10^3 m^2/J (exactly)
10-6.1	spectral angular cross section	10-6.A.a	square centimetre per steradian erg : $cm^2/(sr \cdot erg)$	1 $cm^2/(sr \cdot erg)$ = 10^3 $m^2/(sr \cdot J)$ (exactly)
10-11.1	energy fluence rate	10-11.A.a	erg per square centimetre second : $erg/(cm^2 \cdot s)$	1 $erg/(cm^2 \cdot s)$ = 10^{-3} W/m^2 (exactly)
10-18.1	total linear stopping power	10-18.A.a	erg per centimetre : erg/cm	1 erg/cm = 10^{-5} J/m (exactly)
10-19.1	total atomic stopping power	10-19.A.a	erg square centimetre : $erg \cdot cm^2$	1 $erg \cdot cm^2$ = 10^{-11} $J \cdot m^2$ (exactly)
10-20.1	total mass stopping power	10-20.A.a	erg square centimetre per gram : $erg \cdot cm^2/g$	1 $erg \cdot cm^2/g$ = 10^{-8} $J \cdot m^2/kg$ (exactly)
10-25.1	average energy loss per ion pair formed	10-25.A.a	erg : erg	1 erg = 10^{-7} J (exactly)
10-51.1 10-51.2	specific energy imparted absorbed dose	10-51.A.a	erg per gram : erg/g	1 erg/g = 10^{-4} Gy = 10^{-4} J/kg (exactly)
10-53.1	absorbed dose rate	10-53.A.a	erg per gram second : $erg/(g \cdot s)$	1 $erg/(g \cdot s)$ = 10^{-4} W/kg (exactly)
10-54.1	linear energy transfer	10-54.A.a	erg per centimetre : erg/cm	1 erg/cm = 10^{-5} J/m (exactly)
10-55.1	kerma	10-55.A.a	erg per gram : erg/g	1 erg/g = 10^{-4} Gy = 10^{-4} J/kg (exactly)
10-56.1	kerma rate	10-56.A.a	erg per gram second : $erg/(g \cdot s)$	1 $erg/(g \cdot s)$ = 10^{-4} Gy/s = 10^{-4} W/ kg (exactly)

(1) The annex is not an integral part of this standard.

Mathematical signs and symbols for use in the physical sciences and technology

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Signes et symboles mathématiques à employer dans les sciences physiques et dans la technique

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INTERNATIONAL STANDARD
NORME INTERNATIONALE

ISO 31/XI-1978 (E/F)

Mathematical signs and symbols for use in the physical sciences and technology

Signes et symboles mathématiques à employer dans les sciences physiques et dans la technique

INTRODUCTION

This document, containing a table of *mathematical signs and symbols for use in the physical sciences and technology*, is part XI of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General introduction — General principles concerning quantities, units and symbols.*

Part I : *Quantities and units of space and time.*

Part II : *Quantities and units of periodic and related phenomena.*

Part III : *Quantities and units of mechanics.*

Part IV : *Quantities and units of heat.*

Part V : *Quantities and units of electricity and magnetism.*

Part VI : *Quantities and units of light and related electromagnetic radiations.*

Part VII : *Quantities and units of acoustics.*

Part VIII : *Quantities and units of physical chemistry and molecular physics.*

Part IX : *Quantities and units of atomic and nuclear physics.*

Part X : *Quantities and units of nuclear reactions and ionizing radiations.*

Part XI : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part XII : *Dimensionless parameters.*

Part XIII : *Quantities and units of solid state physics.*

Special remarks

The recommendations in this document are prepared mainly for use in the physical sciences and technology.

If more than one sign, symbol or expression is given under the same item, they are on an equal footing. Signs, symbols and expressions in the remarks column are given for information.

INTRODUCTION

Le présent document, contenant un tableau de *signes et symboles mathématiques à employer dans les sciences physiques et dans la technique*, est la partie XI de l'ISO 31, qui spécifie les grandeurs et unités dans différents domaines de la science et de la technique. La liste complète des parties de l'ISO 31 est la suivante :

Partie 0 : *Introduction générale — Principes généraux concernant les grandeurs, les unités et les symboles.*

Partie I : *Grandeurs et unités d'espace et de temps.*

Partie II : *Grandeurs et unités de phénomènes périodiques et connexes.*

Partie III : *Grandeurs et unités de mécanique.*

Partie IV : *Grandeurs et unités de chaleur.*

Partie V : *Grandeurs et unités d'électricité et de magnétisme.*

Partie VI : *Grandeurs et unités de lumière et de rayonnements électromagnétiques connexes.*

Partie VII : *Grandeurs et unités d'acoustique.*

Partie VIII : *Grandeurs et unités de chimie physique et de physique moléculaire.*

Partie IX : *Grandeurs et unités de physique atomique et nucléaire.*

Partie X : *Grandeurs et unités de réactions nucléaires et rayonnements ionisants.*

Partie XI : *Signes et symboles mathématiques à employer dans les sciences physiques et dans la technique.*

Partie XII : *Paramètres sans dimension.*

Partie XIII : *Grandeurs et unités de la physique de l'état solide.*

Remarques spéciales

Les recommandations dans ce document sont préparées principalement pour emploi dans les sciences physiques et dans la technique.

Lorsque deux ou plusieurs signes, symboles ou expressions sont indiqués sous le même point, ils sont également admissibles. Signes, symboles et expressions dans la colonne «Remarques» sont donnés dans un but d'identification.

1 Theory of sets / Théorie des ensembles

Item No.	Symbol, Sign Symbole, signe	Application Utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-1.1	$\in$	$x \in A$	x belongs to A, x is an element of the set A x appartient à A, x est un élément de l'ensemble A	
11-1.2	$\notin$	$y \notin A$	y does not belong to A, y is not an element of the set A y n'appartient pas à A, y n'est pas un élément de l'ensemble A	
11-1.3	$\ni$	$A \ni x$	the set A contains x (as element) l'ensemble A contient x (comme élément)	
11-1.4	$\not\ni$	$A \not\ni y$	the set A does not contain y (as element) l'ensemble A ne contient pas y (comme élément)	
11-1.5	$\{\ldots\}$	$\{x_1, x_2, \ldots, x_n\}$	set with elements $x_1, x_2, \ldots, x_n$ ensemble dont les éléments sont $x_1, x_2, \ldots, x_n$	Also $\{x_i \mid i \in I\}$, where I denotes a set of indices S'écrit aussi $\{x_i \mid i \in I\}$ où I est un ensemble d'indices
11-1.6	$\{ \mid \}$	$\{x \in A \mid p(x)\}$	set of those elements of A for which the proposition $p(x)$ is true ensemble des éléments de A pour lesquels la proposition $p(x)$ est vraie	Example: $\{x \in \mathrm{R} \mid x \leqslant 5\}$ Exemple: If it is clear from the context which set A is considered, the notation $\{x \mid p(x)\}$ can be used Example: $\{x \mid x \leqslant 5\}$ Si le contexte permet de savoir clairement quel est l'ensemble A considéré, on peut utiliser la notation $\{x \mid p(x)\}$ Exemple: $\{x \mid x \leqslant 5\}$
11-1.7	$\emptyset$		the empty set l'ensemble vide	
11-1.8	N $\mathbb{N}$		the set of positive integers and zero l'ensemble des (nombres) entiers positifs et zéro	$\mathrm{N} = \{0, 1, 2, 3, \ldots\}$ Exclusion of zero from the sets 11-1.8 to 11-1.12 is denoted by an asterisk, e.g. N^* L'exclusion de zéro des ensembles 11-1.8 à 11-1.12 est notée par un astérisque, exemple N^*

1 Theory of sets (continued) / Théorie des ensembles (suite)

Item No.	Symbol, Sign Symbole, signe	Application Utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-1.9	Z $\mathbb{Z}$		the set of integers l'ensemble des (nombres) entiers	$\mathsf{Z} = \{\ldots, -2, -1, 0, 1, 2, \ldots\}$ See remark to 11-1.8 Voir remarque de 11-1.8
11-1.10	Q $\mathbb{Q}$		the set of rational numbers l'ensemble des (nombres) rationnels	See remark to 11-1.8 Voir remarque de 11-1.8
11-1.11	R $\mathbb{R}$		the set of real numbers l'ensemble des (nombres) réels	See remark to 11-1.8 Voir remarque de 11-1.8
11-1.12	C $\mathbb{C}$		the set of complex numbers l'ensemble des (nombres) complexes	See remark to 11-1.8 Voir remarque de 11-1.8
11-1.13	$\subseteq$	$B \subseteq A$	B is included in A, B is a subset of A B est inclus dans A, B est contenu dans A, B est une partie de A	Every element of B belongs to A. $\subset$ is also used, but see remark to 11-1.14 Tout élément de B appartient à A. $\subset$ est aussi utilisé, mais voir remarque de 11-1.14
11-1.14	$\subset$	$B \subset A$	B is properly included in A, B is a proper subset of A B est strictement inclus dans A, B est strictement contenu dans A	Every element of B belongs to A, but B is not equal to A. If $\subset$ is used for 11-1.13, then $\subsetneq$ should be used for 11-1.14 Tout élément de B appartient à A, mais B n'est pas égal à A. Si $\subset$ est utilisé pour 11-1.13, $\subsetneq$ doit être utilisé pour 11-1.14
11-1.15	$\not\subseteq$	$C \not\subseteq A$	C is not included in A, C is not a subset of A C n'est pas inclus dans A, C n'est pas contenu dans A, C n'est pas une partie de A	$\not\subset$ is also used $\not\subset$ est aussi utilisé
11-1.16	$\supseteq$	$A \supseteq B$	A includes B (as subset) A contient B (comme partie)	A contains every element of B. $\supset$ is also used, but see remark to 11-1.17 A contient tout élément de B. $\supset$ est aussi utilisé, mais voir remarque de 11-1.17
11-1.17	$\supset$	$A \supset B$	A includes B properly A contient B strictement	A contains every element of B, but A is not equal to B. If $\supset$ is used for 11-1.16, then $\supsetneq$ should be used for 11-1.17 A contient tout élément de B, mais A n'est pas égal à B. Si $\supset$ est utilisé pour 11-1.16, $\supsetneq$ doit être utilisé pour 11-1.17

1 Theory of sets (continued) / Théorie des ensembles (suite)

Item No.	Symbol, Sign Symbole, signe	Application Utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-1.18	$\nsupseteq$	$A \nsupseteq C$	A does not include C (as subset) A ne contient pas C (comme sous-ensemble)	$\not\supset$ is also used $\not\supset$ est aussi utilisé
11-1.19	$\cup$	$A \cup B$	union of A and B réunion de A et de B	The set of all elements which belong to A or to B or to A and B $A \cup B = \{x \mid x \in A \vee x \in B\}$ L'ensemble des éléments appartenant à A, ou à B ou à A et à B $A \cup B = \{x \mid x \in A \vee x \in B\}$
11-1.20	$\bigcup$	$\bigcup_{i=1}^{n} A_i$	union of a collection of sets $A_1, \ldots, A_n$ réunion des ensembles $A_1, \ldots, A_n$	$\bigcup_{i=1}^{n} A_i = A_1 \cup A_2 \cup \ldots \cup A_n$, the set of all elements belonging at least to one of the sets $A_1, \ldots, A_n$ $\bigcup_{i=1}^{n}$ and $\bigcup_{i \in I}$, $\bigcup_{i \in I}$ are also used, where I denotes a set of indices $\bigcup_{i=1}^{n} A_i = A_1 \cup A_2 \cup \ldots \cup A_n$, l'ensemble des éléments appartenant au moins à un des ensembles $A_1, \ldots, A_n$ $\bigcup_{i=1}^{n}$ et $\bigcup_{i \in I}$, $\bigcup_{i \in I}$ sont aussi utilisés, où I est un ensemble d'indices
11-1.21	$\cap$	$A \cap B$	intersection of A and B, A inter B intersection de A et de B, A inter B	The set of all elements which belong to both A and B $A \cap B = \{x \mid x \in A \wedge x \in B\}$ L'ensemble des éléments appartenant à la fois à A et à B $A \cap B = \{x \mid x \in A \wedge x \in B\}$
11-1.22	$\bigcap$	$\bigcap_{i=1}^{n} A_i$	intersection of a collection of sets $A_1, \ldots, A_n$ intersection des ensembles $A_1, \ldots, A_n$	$\bigcap_{i=1}^{n} A_i = A_1 \cap A_2 \cap \ldots \cap A_n$, the set of all elements belonging to all sets $A_1, A_2, \ldots$ and A_n $\bigcap_{i=1}^{n}$ and $\bigcap_{i \in I}$, $\bigcap_{i \in I}$ are also used, where I denotes a set of indices $\bigcap_{i=1}^{n} A_i = A_1 \cap A_2 \cap \ldots \cap A_n$, ensemble des éléments appartenant à la fois à $A_1, A_2, \ldots$ et A_n $\bigcap_{i=1}^{n}$ et $\bigcap_{i \in I}$, $\bigcap_{i \in I}$ sont aussi utilisés, où I est un ensemble d'indices

1 Theory of sets (concluded) / Théorie des ensembles (fin)

Item No.	Symbol, Sign / Symbole, signe	Application / Utilisation	Meaning, Reading / Sens, énoncé	Remarks and Examples / Remarques et exemples
11-1.23	$\setminus$	$A \setminus B$	difference of A and B, A minus B différence de A et de B, A moins B	The set of all elements which belong to A, but not to B $A \setminus B = \{x \mid x \in A \text{ and } x \notin B\}$ $A - B$ is also used L'ensemble des éléments de A n'appartenant pas à B $A \setminus B = \{x \mid x \in A \text{ et } x \notin B\}$ $A - B$ est aussi utilisé The symmetrical difference $(A \cup B) \setminus (A \cap B) = (A \setminus B) \cup (B \setminus A)$ may be denoted by $A \Delta B$ La différence symétrique $(A \cup B) \setminus (A \cap B) = (A \setminus B) \cup (B \setminus A)$ peut être notée $A \Delta B$
11-1.24	$\complement$	$\complement_U A$	complement of subset A of U complémentaire de la partie A de U	The set of all elements of U which do not belong to the subset A. If it is clear from the context which set U is considered, the symbol U is often omitted. Also $\complement_U A = U \setminus A$ L'ensemble des éléments (d'un ensemble U) n'appartenant pas à la partie A de U. Si le contexte permet de savoir clairement quel est l'ensemble U considéré, le symbole U est souvent omis. On a aussi $\complement_U A = U \setminus A$
11-1.25	$(\ ,\ )$	(a, b)	ordered pair a, b, couple a, b couple a, b	$(a, b) = (c, d)$ if and only if $a = c$ and $b = d$ $\langle a, b \rangle$ is also used $(a, b) = (c, d)$ si et seulement si $a = c$ et $b = d$ $\langle a, b \rangle$ est aussi utilisé
11-1.26	$(\ ,\ldots,\ )$	$(a_1, \ldots, a_n)$	ordered n-tuplet n-uplet, multiplet	
11-1.27	$\times$	$A \times B$	cartesian product of A and B produit (cartésien) de A et de B	The set of all ordered pairs (a, b) such that $a \in A$ and $b \in B$ $A \times B = \{(a, b) \mid a \in A \wedge b \in B\}$ L'ensemble des couples (a, b) pour lesquels $a \in A$ et $b \in B$ $A \times B = \{(a, b) \mid a \in A \wedge b \in B\}$ $A \times A \times \ldots \times A$ is denoted A^n, where n is the number of factors in the product $A \times A \times \ldots \times A$ est noté A^n où n est le nombre de facteurs du produit

2 Symbols of mathematical logic / Symboles de logique mathématique

Item No.	Symbol / Symbole	Application / Utilisation	Name of Symbol / Nom du symbole	Meaning, Reading and Remarks / Sens, énoncé et remarques
11-2.1	$\wedge$	$p \wedge q$	conjunction sign signe de conjonction	p and q p et q
11-2.2	$\vee$	$p \vee q$	disjunction sign signe de disjonction	p or q or both p ou q ou les deux
11-2.3	$\neg$	$\neg p$	negation sign signe de négation	Negation of p, not p, non p Négation de p, non p
11-2.4	$\Rightarrow$	$p \Rightarrow q$	implication sign signe d'implication	If p then q, p implies q Can also be written $q \Leftarrow p$ Sometimes $\rightarrow$ is used p entraîne q, p implique q Peut aussi s'écrire $q \Leftarrow p$ $\rightarrow$ est parfois utilisé
11-2.5	$\Leftrightarrow$	$p \Leftrightarrow q$	equivalence sign signe d'équivalence	$p \Rightarrow q$ and $q \Rightarrow p$; p is equivalent to q Sometimes $\leftrightarrow$ is used $p \Rightarrow q$ et $q \Rightarrow p$; p équivaut à q $\leftrightarrow$ est parfois utilisé
11-2.6	$\forall$	$\forall x \in A,\ p(x)$	universal quantifier quantificateur universel	For every x belonging to A the proposition $p(x)$ is true. The comma before $p(x)$ is sometimes omitted; if danger of confusion arises, parentheses shall be used Pour tout x appartenant à A, la proposition $p(x)$ est vraie. La virgule est parfois omise avant $p(x)$; s'il existe un danger de confusion, des parenthèses doivent être utilisées
11-2.7	$\exists$	$\exists x \in A,\ p(x)$	existential quantifier quantificateur existentiel	There exists an x belonging to A for which $p(x)$ is true. The comma before $p(x)$ is sometimes omitted; if danger of confusion arises, parentheses shall be used Pour au moins un élément x de A, $p(x)$ est vrai. La virgule est parfois omise avant $p(x)$; s'il existe un danger de confusion, des parenthèses doivent être utilisées $\exists!$ or $\overset{1}{\exists}$ is used to indicate the existence of one and only one element with the property in question $\exists!$ ou $\overset{1}{\exists}$ est utilisé pour indiquer l'existence d'un élément et d'un seul avec la propriété en question

Item No.	Symbol Symbole	Application Utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-3.1	$=$	$a = b$	a is equal to b a est égal à b	≡ may be used to emphasize that an equality is a mathematical identity ≡ peut être utilisé pour souligner le fait qu'une égalité est une identité mathématique
11-3.2	$\neq$	$a \neq b$	a is not equal to b a est différent de b	
11-3.3	$\stackrel{\text{def}}{=}$	$a \stackrel{\text{def}}{=} b$	a is by definition equal to b a est égal par définition à b	Example: $p \stackrel{\text{def}}{=} mv$, where p is momentum, m is mass and v is velocity Exemple: $p \stackrel{\text{def}}{=} mv$, où p est la quantité de mouvement, m la masse et v la vitesse
11-3.4	$\triangleq$	$a \triangleq b$	a corresponds to b a correspond à b	Since $E = kT$, 1 eV $\triangleq$ 11 604,5 K When 1 cm on a map corresponds to a length of 10 km, one may write 1 cm $\triangleq$ 10 km Etant donné que $E = kT$, 1 eV $\triangleq$ 11604,5 K Lorsque 1 cm sur une carte correspond à une longueur de 10 km, on peut écrire 1 cm $\triangleq$ 10 km
11-3.5	$\approx$	$a \approx b$	a is approximately equal to b a est approximativement égal à b	
11-3.6	$\sim$ $\propto$	$a \sim b$ $a \propto b$	a is proportional to b a est proportionnel à b	
11-3.7	$<$	$a < b$	a is less than b a est strictement inférieur à b	
11-3.8	$>$	$a > b$	a is greater than b a est strictement supérieur à b	
11-3.9	$\leqslant$	$a \leqslant b$	a is less than or equal to b a est inférieur ou égal à b	

Item No.	Symbol Symbole	Application Utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-3.10	$\geqslant$	$a \geqslant b$	a is greater than or equal to b a est supérieur ou égal à b	
11-3.11	$\ll$	$a \ll b$	a is much less than b a est très inférieur à b	
11-3.12	$\gg$	$a \gg b$	a is much greater than b a est très supérieur à b	
11-3.13	∞		infinity infini	

4 Operations / Opérations

Item No.	Symbol, Application Symbole, utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-4.1	$a+b$	a plus b a plus b	
11-4.2	$a-b$	a minus b a moins b	
11-4.3	$a\cdot b$ $a\times b$ ab	a multiplied by b a multiplié par b	See also 11-1.27, 11-10.6 and 11-10.7 The sign for multiplication of numbers is a cross ($\times$) or a dot half high ($\cdot$). If a dot is used as the decimal sign, only the cross should be used for multiplication of numbers Voir aussi 11-1.27, 11-10.6 et 11-10.7 Le signe de multiplication des nombres est une croix ($\times$) ou un point à mi-hauteur ($\cdot$). Si un point est utilisé comme signe décimal, seule la croix doit être utilisée pour la multiplication des nombres
11-4.4	$\frac{a}{b}$ a/b ab^{-1}	a divided by b a divisé par b	See also ISO 31/0 Voir aussi ISO 31/0
11-4.5	$\sum_{i=1}^{n} a_i$	$a_1+a_2+\ldots+a_n$	Also Aussi $\sum_{i=1}^{n} a_i$ $\sum_{i} a_i$ $\sum_{i} a_i$ $\sum a_i$
11-4.6	$\prod_{i=1}^{n} a_i$	$a_1\cdot a_2\cdot\ldots\cdot a_n$	Also Aussi $\prod_{i=1}^{n} a_i$ $\prod_{i} a_i$ $\prod_{i} a_i$ $\prod a_i$
11-4.7	a^p	a to the power p a puissance p	
11-4.8	$a^{1/2}$ $a^{\frac{1}{2}}$ $\sqrt{a}$ $\sqrt{a}$	a to the power $\frac{1}{2}$, square root of a a puissance $\frac{1}{2}$, racine carrée de a	See remark to 11-4.9 Voir remarque de 11-4.9
11-4.9	$a^{1/n}$ $a^{\frac{1}{n}}$ $\sqrt[n]{a}$ $\sqrt[n]{a}$	a to the power $1/n$, nth root of a a puissance $1/n$, racine n-ième de a	If the symbol $\sqrt{}$ or $\sqrt[n]{}$ acts on a composite expression, parentheses should be used to avoid ambiguity Si les symboles $\sqrt{}$ ou $\sqrt[n]{}$ s'appliquent à une expression composée, il faut employer des parenthèses pour éviter toute ambiguité

4 Operations (concluded) / Opérations (fin)

Item No.	Symbol, Application Symbole, utilisation	Meaning, Reading Sens, énoncé	Remarks and Examples Remarques et exemples
11-4.10	$\lvert a\rvert$	absolute value of a, magnitude of a, modulus of a valeur absolue de a, module de a	abs a is also used abs a est aussi utilisé
11-4.11	sgn a	signum a signum a	For real a: $\operatorname{sgn} a = \begin{cases} 1 & \text{for } a>0 \\ 0 & \text{for } a=0 \\ -1 & \text{for } a<0 \end{cases}$ For complex a, see 11-8.7 Pour a réel: $\operatorname{sgn} a = \begin{cases} 1 & \text{pour } a>0 \\ 0 & \text{pour } a=0 \\ -1 & \text{pour } a<0 \end{cases}$ Pour a complexe, voir 11-8.7
11-4.12	$\bar{a}$ $\langle a\rangle$	mean value of a valeur moyenne de a	The method of forming the mean should be stated if not clear from the context La méthode de formation de la moyenne doit être spécifiée si elle ne ressort pas du contexte
11-4.13	$n!$	factorial n factorielle n	For $n\geqslant 1$: $n!=\prod_{k=1}^{n} k=1\times 2\times 3\times\ldots\times n$ For $n=0$: $n!=1$ Pour $n\geqslant 1$: $n!=\prod_{k=1}^{n} k=1\times 2\times 3\times\ldots\times n$ Pour $n=0$: $n!=1$
11-4.14	$\binom{n}{p}$ C_n^p	binomial coefficient coefficient binomial	$\binom{n}{p}=\frac{n!}{p!\,(n-p)!}$
11-4.15	ent a	the greatest integer less than or equal to a caractéristique de a; le plus grand nombre entier inférieur ou égal à a	ent 2,4 = 2 ent(−2,4) = −3 E(a) is also used. [a] is sometimes used for ent$a$, but is now often used with the meaning "integer part of a", e.g. [2,4] = 2 [−2,4] = −2 E(a) est aussi utilisé. [a] est parfois employé pour ent$a$, mais est souvent utilisé actuellement avec la signification "partie entière de a", par exemple: [2,4] = 2 [−2,4] = −2

5 Functions / Fonctions

Item No.	Symbol, Application Symbole, utilisation	Meaning Sens	Remarks and Examples Remarques et exemples
11-5.1	f ·	function f fonction f	A function may also be denoted by $x \mapsto f(x)$ Une fonction peut aussi s'écrire $x \mapsto f(x)$
11-5.2	$f(x)$ $f(x,y,\ldots)$	value of the function f at x or at $(x,y,\ldots)$ respectively valeur de la fonction f respectivement en x ou en $(x,y,\ldots)$	
11-5.3	$[f(x)]_a^b$ $f(x)\|_a^b$	$f(b)-f(a)$	This notation is used mainly when evaluating integrals Cette notation est principalement utilisée pour le calcul des intégrales
11-5.4	$g \circ f$	the composite function of f and g fonction composée de f et g	$(g \circ f)(x) = g(f(x))$
11-5.5	$x \to a$	x tends to a x tend vers a	
11-5.6	$\lim\limits_{x \to a} f(x)$ $\lim_{x \to a} f(x)$	limit of $f(x)$ as x tends to a limite de $f(x)$ quand x tend vers a	$\lim_{x \to a} f(x) = b$ may be written $f(x) \to b$ as $x \to a$ Limits "from the right" $(x > a)$ and "from the left" $(x < a)$ may be denoted $\lim_{x \to a+} f(x)$ and $\lim_{x \to a-} f(x)$ respectively $\lim_{x \to a} f(x) = b$ peut s'écrire $f(x) \to b$ quand $x \to a$ Les limites "à droite" $(x > a)$ et "à gauche" $(x < a)$ peuvent s'écrire respectivement $\lim_{x \to a+} f(x)$ et $\lim_{x \to a-} f(x)$
11-5.7	$\simeq$	is asymptotically equal to est asymptotiquement égal à	$\dfrac{1}{\sin(x-a)} \simeq \dfrac{1}{x-a}$ as $x \to a$ $\dfrac{1}{\sin(x-a)} \simeq \dfrac{1}{x-a}$ quand $x \to a$
11-5.8	$O(g(x))$	of order comparable with or inferior to $g(x)$ d'ordre comparable ou inférieur à $g(x)$	$f(x) = O(g(x))$ means $\|f(x)/g(x)\|$ is bounded above in the limit implied by the context $f(x) = O(g(x))$ signifie que $\|f(x)/g(x)\|$ est borné supérieurement dans la limite impliquée par le contexte

5 Functions (continued) / Fonctions (suite)

Item No.	Symbol, Application Symbole, utilisation	Meaning Sens	Remarks and Examples Remarques et exemples
11-5.9	$o(g(x))$	of order inferior to $g(x)$ d'ordre inférieur à $g(x)$	$f(x) = o(g(x))$ means $f(x)/g(x) \to 0$ in the limit implied by the context $f(x) = o(g(x))$ signifie $f(x)/g(x) \to 0$ dans la limite impliquée par le contexte
11-5.10	Δx	(finite) increment of x accroissement de x	
11-5.11	$\dfrac{df}{dx}$ df/dx f' Df	derivative of the function f of one variable dérivée de la fonction f d'une variable	$\dfrac{df(x)}{dx}$, $df(x)/dx$, $f'(x)$, $Df(x)$ If the independent variable is time t, $\dot{f}$ is also used for $\dfrac{df}{dt}$ Si la variable indépendante est le temps t, $\dot{f}$ est aussi utilisé pour $\dfrac{df}{dt}$
11-5.12	$\left(\dfrac{df}{dx}\right)_{x=a}$ $(df/dx)_{x=a}$ $f'(a)$ $Df(a)$	value at a of the derivative of the function f valeur de la dérivée de la fonction f pour la valeur a de la variable	
11-5.13	$\dfrac{d^n f}{dx^n}$ $d^n f/dx^n$ $f^{(n)}$ $D^n f$	nth derivative of the function f of one variable dérivée n-ième de la fonction f d'une variable	For $n = 2, 3, f'', f'''$ are also used for $f^{(n)}$ If the independent variable is time t, $\ddot{f}$ is also used for $\dfrac{d^2 f}{dt^2}$ Pour $n = 2, 3, f'', f'''$ sont aussi utilisés pour $f^{(n)}$. Si la variable indépendante est le temps t, $\ddot{f}$ est aussi utilisé pour $\dfrac{d^2 f}{dt^2}$

5 *Functions (continued) / Fonctions (suite)*

Item No.	Symbol, Application Symbole, utilisation	Meaning Sens	Remarks and Examples Remarques et exemples
11-5.14	$\frac{\partial f}{\partial x}$ $\partial f/\partial x$ $\partial_x f$ $\mathrm{D}_x f$	partial derivative of the function f of several variables $x, y, \ldots$ with respect to x dérivée partielle de la fonction f de plusieurs variables $x, y, \ldots$ par rapport à x	$\frac{\partial f(x,y,\ldots)}{\partial x}$ $\quad \partial f(x,y,\ldots)/\partial x$ $\partial_x f(x,y,\ldots)$ $\quad \mathrm{D}_x f(x,y,\ldots)$ The other independent variables may be shown as subscripts, e.g. $\left(\frac{\partial f}{\partial x}\right)_{y,\ldots}$ Les autres variables indépendantes peuvent être indiquées en indices, par exemple $\left(\frac{\partial f}{\partial x}\right)_{y,\ldots}$ This partial derivative notation is extended to derivatives of higher order, e.g. $\frac{\partial^2 f}{\partial x^2}, \frac{\partial^2 f}{\partial x \partial y}$ La notation de la dérivée partielle peut aussi s'employer pour les dérivées d'ordre supérieur, par exemple $\frac{\partial^2 f}{\partial x^2}, \frac{\partial^2 f}{\partial x \partial y}$
11-5.15	$\mathrm{d}f$	total differential of the function f différentielle de la fonction f, différentielle totale de la fonction f	$\mathrm{d}f(x,y,\ldots) = \frac{\partial f}{\partial x}\mathrm{d}x + \frac{\partial f}{\partial y}\mathrm{d}y + \ldots$
11-5.16	δf	(infinitesimal) variation of the function f variation (infinitésimale) de la fonction f	
11-5.17	$\int f(x)\mathrm{d}x$	an indefinite integral of the function f or the set of indefinite integrals of the function f une primitive de la fonction f ou l'ensemble des primitives de la fonction f	

5 *Functions (concluded) / Fonctions (fin)*

Item No.	Symbol, Application Symbole, utilisation	Meaning Sens	Remarks and Examples Remarques et exemples
11-5.18	$\int_a^b f(x)\,\mathrm{d}x$ $\quad \int_a^b f(x)\,\mathrm{d}x$	definite integral of the function f from a to b intégrale de la fonction f de a à b	Special notations $\int_C \quad \int_S \quad \int_V \quad \oint$ are used for integration over a curve C, a surface S and a volume V, and over a closed curve or surface, respectively Les notations spéciales $\int_C \quad \int_S \quad \int_V \quad \oint$ sont utilisées respectivement pour l'intégration sur une courbe C, une surface S, un volume V, et sur une courbe ou une surface fermée
11-5.19	δ_{ik}	Kronecker delta symbol symbole delta de Kronecker	$\delta_{ik} = \begin{cases} 1 & \text{for } i = k \\ 0 & \text{for } i \neq k \end{cases}$ where i and k are integers $\delta_{ik} = \begin{cases} 1 & \text{pour } i = k \\ 0 & \text{pour } i \neq k \end{cases}$ où i et k sont entiers
11-5.20	ε_{ijk}	Levi-Civita symbol symbole de Levi-Civita	$\varepsilon_{ijk} = 1$ for $(i,j,k) = (1,2,3)$ and is completely antisymmetric in the indices ε_{ijk} est égale à 1 pour $(i,j,k) = (1,2,3)$ et est totalement antisymétrique par rapport aux indices
11-5.21	$\delta(x)$	Dirac delta distribution (function) distribution (delta) de Dirac	$\int_{-\infty}^{+\infty} f(x)\delta(x)\,\mathrm{d}x = f(0)$
11-5.22	$\epsilon(x)$	unit step function, Heaviside function fonction échelon unité, fonction de Heaviside	$\epsilon(x) = \begin{cases} 1 & \text{for } x > 0 \\ 0 & \text{for } x < 0 \end{cases}$ $\mathrm{H}(x)$ and $\gamma(x)$ are also used $\theta(x)$ is used for unit step function of time $\epsilon(x) = \begin{cases} 1 & \text{pour } x > 0 \\ 0 & \text{pour } x < 0 \end{cases}$ $\mathrm{H}(x)$ et $\gamma(x)$ sont aussi utilisés $\theta(x)$ est utilisé pour la fonction échelon du temps
11-5.23	$f * g$	convolution product of f and g produit de convolution de f et g	$(f*g)(x) = \int_{-\infty}^{+\infty} f(y)g(x-y)\,\mathrm{d}y$

6 Exponential and logarithmic functions / Fonctions exponentielles et logarithmiques

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-6.1	e	base of natural logarithms base des logarithmes népériens	
11-6.2	e^x $\exp x$	exponential function (to the base e) of x exponentielle (de base e) de x	
11-6.3	$\log_a x$	logarithm to the base a of x logarithme de base a de x	
11-6.4	$\ln x$ $\log_e x$	natural logarithm of x logarithme népérien de x	$\log x$ is often used in place of $\ln x$ or $\lg x$. It should then be made clear from the context which base is implied $\log x$ est souvent utilisé à la place de $\ln x$ ou $\lg x$. Le contexte doit indiquer clairement quelle est la base employée
11-6.5	$\lg x$ $\log_{10} x$	common (Briggsian) logarithm of x logarithme décimal (briggsien) de x	
11-6.6	$\mathrm{lb}\, x$ $\log_2 x$	binary logarithm of x logarithme binaire de x	

7 Circular and hyperbolic functions / Fonctions circulaires et hyperboliques

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-7.1	π	ratio of the circumference of a circle to its diameter rapport de la longueur d'un cercle à son diamètre	
11-7.2	$\sin x$	sine of x sinus x	
11-7.3	$\cos x$	cosine of x cosinus x	
11-7.4	$\tan x$	tangent of x tangente x	$\mathrm{tg}\, x$ is also used $\mathrm{tg}\, x$ est aussi utilisé
11-7.5	$\cot x$	cotangent of x cotangente x	$\mathrm{ctg}\, x$ is also used $\mathrm{ctg}\, x$ est aussi utilisé
11-7.6	$\sec x$	secant of x, $\frac{1}{\cos x}$ sécante x, $\frac{1}{\cos x}$	
11-7.7	$\mathrm{cosec}\, x$	cosecant of x, $\frac{1}{\sin x}$ cosécante x, $\frac{1}{\sin x}$	$\mathrm{csc}\, x$ is also used $\mathrm{csc}\, x$ est aussi utilisé
11-7.8	$\arcsin x$	arc sine of x arc sinus x	With the restriction $-\pi/2 \leqslant y \leqslant \pi/2$ the inverse of the function $x = \sin y$ may be denoted by $y = \mathrm{Arcsin}\, x$ La fonction réciproque de la fonction $x = \sin y$ restreinte à $-\pi/2 \leqslant y \leqslant \pi/2$ peut être notée $y = \mathrm{Arcsin}\, x$

7 Circular and hyperbolic functions (continued) / Fonctions circulaires et hyperboliques (suite)

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-7.9	arccos x	arc cosine of x arc cosinus x	With the restriction $0 \leqslant y \leqslant \pi$ the inverse of the function $x = \cos y$ may be denoted by $y = \mathrm{Arccos}\, x$ La fonction réciproque de la fonction $x = \cos y$ restreinte à $0 \leqslant y \leqslant \pi$ peut être notée $y = \mathrm{Arccos}\, x$
11-7.10	arctan x	arc tangent of x arc tangente x	arctg x is also used arctg x est aussi utilisé With the restriction $-\pi/2 < y < \pi/2$ the inverse of the function $x = \tan y$ may be denoted by $y = \mathrm{Arctan}\, x$ (or $y = \mathrm{Arctg}\, x$) La fonction réciproque de la fonction $x = \tan y$ restreinte à $-\pi/2 < y < \pi/2$ peut être notée $y = \mathrm{Arctan}\, x$ (ou $y = \mathrm{Arctg}\, x$)
11-7.11	arccot x	arc cotangent of x arc cotangente x	arcctg x is also used arcctg x est aussi utilisé With the restriction $0 < y < \pi$ the inverse of the function $x = \cot y$ may be denoted by $y = \mathrm{Arccot}\, x$ La fonction réciproque de la fonction $x = \cot y$ restreinte à $0 < y < \pi$ peut être notée $y = \mathrm{Arccot}\, x$
11-7.12	arcsec x	arc secant of x arc sécante x	
11-7.13	arccosec x	arc cosecant of x arc cosécante x	arccsc x is also used arccsc x est aussi utilisé Remark to 11-7.8 ... 11-7.13 The notations $\sin^{-1} x$, $\cos^{-1} x$ etc. for the inverse circular functions should not be used because they may be mistaken for $(\sin x)^{-1}$, $(\cos x)^{-1}$ etc. Remarque de 11-7.8 à 11-7.13 Les notations $\sin^{-1} x$, $\cos^{-1} x$ etc. pour les fonctions circulaires réciproques ne doivent pas être utilisées parce qu'elles peuvent être confondues avec $(\sin x)^{-1}$, $(\cos x)^{-1}$ etc.

7 Circular and hyperbolic functions (continued) / Fonctions circulaires et hyperboliques (suite)

Item No.	Sign, Symbol Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-7.14	sinh x	hyperbolic sine of x sinus hyperbolique x	sh x is also used sh x est aussi utilisé
11-7.15	cosh x	hyperbolic cosine of x cosinus hyperbolique x	ch x is also used ch x est aussi utilisé
11-7.16	tanh x	hyperbolic tangent of x tangente hyperbolique x	th x is also used th x est aussi utilisé
11-7.17	coth x	hyperbolic cotangent of x cotangente hyperbolique x	cth x is also used cth x est aussi utilisé
11-7.18	sech x	hyperbolic secant of x sécante hyperbolique x	
11-7.19	cosech x	hyperbolic cosecant of x cosécante hyperbolique x	csch x is also used csch x est aussi utilisé
11-7.20	arsinh x	inverse hyperbolic sine of x argument sinus hyperbolique x	arsh x and argsh x are also used arsh x et arg sh x sont aussi utilisés
11-7.21	arcosh x	inverse hyperbolic cosine of x argument cosinus hyperbolique x	arch x and argch x are also used arch x et arg ch x sont aussi utilisés With the restriction $y \geqslant 0$ the inverse of the function $x = \cosh y$ may be denoted by $y = \mathrm{Arcosh}\, x$ La fonction réciproque de la fonction $x = \cosh y$ restreinte à $y \geqslant 0$ peut être notée $y = \mathrm{Arcosh}\, x$

7 Circular and hyperbolic functions (concluded) / Fonctions circulaires et hyperboliques (fin)

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-7.22	artanh x	inverse hyperbolic tangent of x argument tangente hyperbolique x	arth x and argth x are also used arth x et arg th x sont aussi utilisés
11-7.23	arcoth x	inverse hyperbolic cotangent of x argument cotangente hyperbolique x	arg coth x and arcth x are also used arg coth x et arcth x sont aussi utilisés
11-7.24	arsech x	inverse hyperbolic secant of x argument sécante hyperbolique x	
11-7.25	arcosech x	inverse hyperbolic cosecant of x argument cosécante hyperbolique x	arcsch x is also used arcsch x est aussi utilisé Remarks to 11-7.20 ... 11-7.25 Remarques de 11-7.20 à 11-7.25 The word "argument" in the French names should not be confused with the word "argument" as used in 11-8.5 Le terme "argument" dans les termes français ne doit pas être confondu avec le terme "argument" utilisé en 11-8.5 The notations $\sinh^{-1}x$, $\cosh^{-1}x$ etc. for the inverse hyperbolic functions should not be used because they may be mistaken for $(\sinh x)^{-1}$, $(\cosh x)^{-1}$, etc. Les notations $\sinh^{-1}x$, $\cosh^{-1}x$ etc. pour les fonctions hyperboliques réciproques ne doivent pas être utilisées parce qu'elles peuvent être confondues avec $(\sinh x)^{-1}$, $(\cosh x)^{-1}$, etc.

8 Complex numbers / Nombres complexes

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-8.1	i j	imaginary unit, $i^2 = -1$ unité imaginaire, $i^2 = -1$	In electrotechnics j is generally used En électrotechnique, j est généralement utilisé
11-8.2	Re z	real part of z partie réelle de z	
11-8.3	Im z	imaginary part of z partie imaginaire de z	$z = \mathrm{Re}\, z + \mathrm{i}\, \mathrm{Im}\, z$
11-8.4	$\lvert z\rvert$	absolute value of z, modulus of z valeur absolue de z, module de z	
11-8.5	arg z	argument of z, phase of z argument de z, phase de z	$z = \lvert z\rvert \exp(\mathrm{i} \arg z)$ $z = \lvert z\rvert \exp(i\varphi)$ is also used $z = \lvert z\rvert \exp(i\varphi)$ est aussi utilisé
11-8.6	z^*	(complex) conjugate of z (complexe) conjugué de z	Sometimes $\tilde{z}$ is used instead of z^* Parfois $\tilde{z}$ est utilisé au lieu de z^*
11-8.7	sgn z	signum z signum z	$\mathrm{sgn}\, z = z/\lvert z\rvert = \exp(\mathrm{i} \arg z)$ for $z \neq 0$ pour $z \neq 0$

9 Matrices / Matrices

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
			The use of capital letters in this section is not intended to imply that matrices or matrix elements cannot be written with lower case letters L'utilisation de lettres capitales dans ce chapitre ne signifie pas que les matrices ou les éléments de matrice ne puissent être écrits en caractères minuscules
11-9.1	A $\begin{pmatrix} A_{11} \dots A_{1n} \\ \vdots \quad \vdots \\ A_{m1} \dots A_{mn} \end{pmatrix}$	matrix A matrice A	Square brackets are also used On emploie aussi des crochets
11-9.2	AB	product of matrices A and B produit des matrices A et B	$(AB)_{ik} = \sum_j A_{ij} B_{jk}$ where the number of columns of A must be equal to the number of rows of B où le nombre de colonnes de A doit être égal au nombre de lignes de B
11-9.3	$E \quad I$	unit matrix matrice unité	Square matrix for which $E_{ik} = \delta_{ik}$; see 11-5.19 Matrice carrée pour laquelle $E_{ik} = \delta_{ik}$; voir 11-5.19
11-9.4	A^{-1}	inverse of the square matrix A inverse de la matrice carrée A	$AA^{-1} = A^{-1}A = E$
11-9.5	$\tilde{A} \quad A^{\mathrm{T}}$	transpose matrix of A matrice transposée de A	$(\tilde{A})_{ik} = A_{ki}$ ^tA and A' are also used ^tA et A' sont aussi utilisés
11-9.6	A^*	complex conjugate matrix of A matrice (complexe) conjuguée de A	$(A^*)_{ik} = (A_{ik})^* = A^*_{ik}$ In mathematics, $\bar{A}$ is often used En mathématique, $\bar{A}$ est souvent utilisé
11-9.7	$A^\dagger \quad A^{\mathrm{H}}$	Hermitian conjugate matrix of A matrice adjointe de A	$(A^\dagger)_{ik} = (A_{ki})^* = A^*_{ki}$ In mathematics, A^* is often used En mathématique, A^* est souvent utilisé

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-9.8	$\det A$ $\begin{vmatrix} A_{11} \dots A_{1n} \\ \vdots \quad \vdots \\ A_{n1} \dots A_{nn} \end{vmatrix}$	determinant of the square matrix A déterminant de la matrice carrée A	
11-9.9	$\mathrm{tr}\, A$	trace of the square matrix A trace de la matrice carrée A	$\mathrm{tr}\, A = \sum_i A_{ii}$ $\mathrm{sp}\, A$ is also used $\mathrm{sp}\, A$ est aussi utilisé
11-9.10	$\|A\|$	norm of the matrix A norme de la matrice A	Several matrix norms can be defined, e.g. the Euclidean norm $\|A\| = (\mathrm{tr}(AA^\dagger))^{\frac{1}{2}}$ Plusieurs normes de matrices peuvent être définies, par exemple la norme euclidienne $\|A\| = (\mathrm{tr}(AA^\dagger))^{\frac{1}{2}}$

10 Vectors and tensors / Vecteurs et tenseurs

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
			In this section only cartesian (orthonormal) coordinates in ordinary space are considered. The more general case requiring covariant and contravariant representations is not treated here. The cartesian coordinates are denoted x, y, z or x_1, x_2, x_3. In the latter case indices i, j, k, l ranging from 1 to 3 are used, and the following summation convention is adopted: If an index appears twice in a term, summation over the range of this index is understood On considère seulement dans ce chapitre les coordonnées cartésiennes (orthonormées) dans l'espace ordinaire. Le cas plus général exigeant des représentations covariantes et contravariantes n'est pas traité ici. Les coordonnées cartésiennes sont notées x, y, z ou x_1, x_2, x_3. Dans le dernier cas, des indices i, j, k, l pouvant prendre les valeurs 1, 2, 3 sont utilisés et la convention de sommation suivante est adoptée: si un indice apparait deux fois dans un terme, la sommation sur l'étendue de cet indice est sous-entendue
11-10.1	$\boldsymbol{a}$	vector $\boldsymbol{a}$ vecteur $\boldsymbol{a}$	$\vec{a}$ is also used $\vec{a}$ est aussi utilisé
11-10.2	a $\lvert\boldsymbol{a}\rvert$	magnitude of the vector $\boldsymbol{a}$ norme du vecteur $\boldsymbol{a}$	$\lvert\boldsymbol{a}\rvert$ is also used $\lvert\boldsymbol{a}\rvert$ est aussi utilisé
11-10.3	$\boldsymbol{e}_a$	unit vector in the direction of $\boldsymbol{a}$ vecteur unité ayant la même direction et le même sens que $\boldsymbol{a}$	$\boldsymbol{e}_a = \boldsymbol{a}/\lvert\boldsymbol{a}\rvert$ $\mathbf{1}_a$ is also used $\mathbf{1}_a$ est aussi utilisé
11-10.4	$\boldsymbol{e}_x, \boldsymbol{e}_y, \boldsymbol{e}_z$ $\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k}$ $\boldsymbol{e}_i$	unit vectors in the directions of the cartesian coordinate axes vecteurs d'une base orthonormée	$\mathbf{1}_x, \mathbf{1}_y, \mathbf{1}_z$ are also used $\mathbf{1}_x, \mathbf{1}_y, \mathbf{1}_z$ sont aussi utilisés
11-10.5	a_x, a_y, a_z a_i	cartesian components of vector $\boldsymbol{a}$ coordonnées cartésiennes du vecteur $\boldsymbol{a}$	$\boldsymbol{a} = a_x\boldsymbol{e}_x + a_y\boldsymbol{e}_y + a_z\boldsymbol{e}_z$ $a_x\boldsymbol{e}_x$, etc. are the component vectors $a_x\boldsymbol{e}_x$, etc. sont les composantes

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-10.6	$\boldsymbol{a}\cdot\boldsymbol{b}$	scalar product of $\boldsymbol{a}$ and $\boldsymbol{b}$ produit scalaire de $\boldsymbol{a}$ et $\boldsymbol{b}$	$\boldsymbol{a}\cdot\boldsymbol{b} = a_x b_x + a_y b_y + a_z b_z$ $\boldsymbol{a}\cdot\boldsymbol{a} = \boldsymbol{a}^2 = \lvert\boldsymbol{a}\rvert^2 = a^2$ $a\cdot b = a_i b_i \stackrel{\text{def}}{=} \sum_i a_i b_i$
11-10.7	$\boldsymbol{a}\times\boldsymbol{b}$	vector product of $\boldsymbol{a}$ and $\boldsymbol{b}$ produit vectoriel de $\boldsymbol{a}$ et $\boldsymbol{b}$	The components are $a_y b_z - a_z b_y$, etc. in a right-handed cartesian coordinate system Les coordonnées sont $a_y b_z - a_z b_y$, etc. dans un système direct de coordonnées cartésiennes $\boldsymbol{a}\wedge\boldsymbol{b}$ is also used $\boldsymbol{a}\wedge\boldsymbol{b}$ est aussi utilisé
11-10.8	∇	nabla operator (opérateur) nabla	$\nabla = \boldsymbol{e}_x\frac{\partial}{\partial x} + \boldsymbol{e}_y\frac{\partial}{\partial y} + \boldsymbol{e}_z\frac{\partial}{\partial z} = \boldsymbol{e}_i\frac{\partial}{\partial x_i}$ $\frac{\partial}{\partial \boldsymbol{r}}$ is also used $\frac{\partial}{\partial \boldsymbol{r}}$ est aussi utilisé
11-10.9	$\nabla\varphi$ $\operatorname{grad}\varphi$	gradient of φ gradient de φ	$\operatorname{grad}\varphi$ is also used $\operatorname{grad}\varphi$ est aussi utilisé
11-10.10	$\nabla\cdot\boldsymbol{a}$ $\operatorname{div}\boldsymbol{a}$	divergence of $\boldsymbol{a}$ divergence de $\boldsymbol{a}$	$\nabla\cdot\boldsymbol{a} \stackrel{\text{def}}{=} \sum_i \frac{\partial a_i}{\partial x_i}$
11-10.11	$\nabla\times\boldsymbol{a}$ $\operatorname{rot}\boldsymbol{a}$ $\operatorname{curl}\boldsymbol{a}$	curl of $\boldsymbol{a}$ rotationnel de $\boldsymbol{a}$	$\operatorname{rot}\boldsymbol{a}$, $\operatorname{curl}\boldsymbol{a}$, $\nabla\wedge\boldsymbol{a}$ are also used $\operatorname{rot}\boldsymbol{a}$, $\operatorname{curl}\boldsymbol{a}$, $\nabla\wedge\boldsymbol{a}$ sont aussi utilisés
11-10.12	∇^2 Δ	Laplacian laplacien	$\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$
11-10.13	$\Box$	Dalembertian dalembertien	$\Box = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}$

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-10.14	$\vec{\vec{T}}$	tensor of second order T tenseur du deuxième ordre T	$\vec{\vec{T}}$ is also used $\vec{\vec{T}}$ est aussi utilisé
11-10.15	$T_{xx}, T_{xy}, \ldots, T_{zz}$ T_{ij}	components of tensor T composantes du tenseur T	$T = T_{xx}e_xe_x + T_{xy}e_xe_y + \ldots$
11-10.16	ab $a \otimes b$	dyadic product, tensor product of two vectors a and b produit tensoriel de deux vecteurs a et b	tensor of second order with components a_ib_j $(a_xb_x, a_xb_y, \ldots, a_zb_z)$ tenseur du second ordre de composantes a_ib_j $(a_xb_x, a_xb_y, \ldots, a_zb_z)$
11-10.17	$T \otimes S$	tensor product of two tensors of second order T and S produit tensoriel de deux tenseurs du deuxième ordre T et S	tensor of fourth order with components $T_{ij}S_{kl}$ tenseur du quatrième ordre de composantes $T_{ij}S_{kl}$
11-10.18	$T \cdot S$	inner product of two tensors of second order T and S produit intérieur de deux tenseurs du deuxième ordre T et S	tensor of second order with components $T_{ij}S_{jk} \stackrel{\text{def}}{=} \sum_j T_{ij}S_{jk}$ tenseur du deuxième ordre de composantes $T_{ij}S_{jk} \stackrel{\text{def}}{=} \sum_j T_{ij}S_{jk}$
11-10.19	$T \cdot a$	inner product of a tensor of second order T and a vector a produit intérieur d'un tenseur du deuxième ordre T et d'un vecteur a	vector with components $T_{ij}a_j \stackrel{\text{def}}{=} \sum_j T_{ij}a_j$ vecteur de composantes $T_{ij}a_j \stackrel{\text{def}}{=} \sum_j T_{ij}a_j$
11-10.20	$T : S$	scalar product of two tensors of second order T and S produit scalaire de deux tenseurs du deuxième ordre T et S	scalar quantity $T_{ij}S_{ji} \stackrel{\text{def}}{=} \sum_i \sum_j T_{ij}S_{ji}$ grandeur scalaire $T_{ij}S_{ji} \stackrel{\text{def}}{=} \sum_i \sum_j T_{ij}S_{ji}$
			Remark to 11-10.1 ... 11-10.20 Vectors and tensors are often represented by general symbols for their components, e.g. a_i for a vector, T_{ij} for a tensor of second order, a_ib_j for a dyadic product Remarque de 11-10.1 à 11-10.20 Les vecteurs et les tenseurs sont souvent représentés par les symboles généraux de leurs composantes, par exemple a_i pour un vecteur, T_{ij} pour un tenseur du deuxieme ordre, a_ib_j pour un produit tensoriel

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-11.1	$J_l(x)$	cylindrical Bessel functions (of the first kind) fonctions de Bessel cylindriques (de première espèce)	solutions of / solutions de $x^2y'' + xy' + (x^2 - l^2)y = 0$ $J_l(x) = \sum_{k=0}^{\infty} \frac{(-1)^k (x/2)^{l+2k}}{k!\,\Gamma(l+k+1)}$
11-11.2	$N_l(x)$	cylindrical Neumann functions, cylindrical Bessel functions of the second kind fonctions de Neumann cylindriques, fonctions de Bessel cylindriques de deuxième espèce	$N_l(x) = \lim_{k \to l} \frac{J_k(x)\cos k\pi - J_{-k}(x)}{\sin k\pi}$ $Y_l(x)$ is also used $Y_l(x)$ est aussi utilisé
11-11.3	$H_l^{(1)}(x)$ $H_l^{(2)}(x)$	cylindrical Hankel functions, cylindrical Bessel functions of the third kind fonctions de Hankel cylindriques, fonctions de Bessel cylindriques de troisième espèce	$H_l^{(1)}(x) = J_l(x) + i\,N_l(x)$ $H_l^{(2)}(x) = J_l(x) - i\,N_l(x)$
11-11.4	$I_l(x)$ $K_l(x)$	modified cylindrical Bessel functions fonctions de Bessel cylindriques modifiées	solutions of / solutions de $x^2y'' + xy' - (x^2 + l^2)y = 0$ $I_l(x) = i^{-l}J_l(ix)$ $K_l(x) = (\pi/2)i^{l+1}(J_l(ix) + i\,N_l(ix))$
11-11.5	$j_l(x)$	spherical Bessel functions (of the first kind) fonctions de Bessel sphériques (de première espèce)	solutions of / solutions de $x^2y'' + 2xy' + [x^2 - l(l+1)]y = 0$ $j_l(x) = (\pi/2x)^{\frac{1}{2}}J_{l+\frac{1}{2}}(x)$
11-11.6	$n_l(x)$	spherical Neumann functions, spherical Bessel functions of the second kind fonctions de Neumann sphériques, fonctions de Bessel sphériques de deuxième espèce	$n_l(x) = (\pi/2x)^{\frac{1}{2}}N_{l+\frac{1}{2}}(x)$ $y_l(x)$ is also used $y_l(x)$ est aussi utilisé
11-11.7	$h_l^{(1)}(x)$ $h_l^{(2)}(x)$	spherical Hankel functions, spherical Bessel functions of the third kind fonctions de Hankel sphériques, fonctions de Bessel sphériques de troisième espèce	$h_l^{(1)}(x) = j_l(x) + i\,n_l(x) = (\pi/2x)^{\frac{1}{2}}H_{l+\frac{1}{2}}^{(1)}(x)$ $h_l^{(2)}(x) = j_l(x) - i\,n_l(x) = (\pi/2x)^{\frac{1}{2}}H_{l+\frac{1}{2}}^{(2)}(x)$ Modified spherical Bessel functions are denoted $i_l(x)$ and $k_l(x)$ respectively; compare 11-11.4 Les fonctions de Bessel sphériques modifiées sont notées respectivement $i_l(x)$ et $k_l(x)$; voir 11-11.4

11 Special functions (continued) / Fonctions spéciales (suite)

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-11.8	$P_l(x)$	Legendre polynomials polynômes de Legendre	solutions of / solutions de $(1-x^2)y''-2xy'+l(l+1)y=0$ $P_l(x)=\frac{1}{2^l l!}\frac{d^l}{dx^l}(x^2-1)^l \quad (l=0,1,2,\ldots)$
11-11.9	$P_l^m(x)$	associated Legendre functions fonctions de Legendre associées	solutions of / solutions de $(1-x^2)y''-2xy'+\left[l(l+1)-\frac{m^2}{1-x^2}\right]y=0$ $P_l^m(x)=(1-x^2)^{\frac{m}{2}}\frac{d^m}{dx^m}P_l(x)$ $(l,m=0,1,2,\ldots;\ m\leqslant l)$
11-11.10	$Y_l^m(\vartheta,\varphi)$	spherical harmonics harmoniques sphériques	solutions of / solutions de $\frac{1}{\sin\vartheta}\frac{\partial}{\partial\vartheta}\left(\sin\vartheta\frac{\partial y}{\partial\vartheta}\right)+\frac{1}{\sin^2\vartheta}\frac{\partial^2 y}{\partial\varphi^2}+l(l+1)y=0$ $Y_l^m(\vartheta,\varphi)=(-1)^m\left[\frac{(2l+1)}{4\pi}\frac{(l-m)!}{(l+m)!}\right]^{\frac{1}{2}}\times P_l^m(\cos\vartheta)e^{im\varphi}$ $(l,\lvert m\rvert=0,1,2,\ldots;\ \lvert m\rvert\leqslant l)$
11-11.11	$H_n(x)$	Hermite polynomials polynômes d'Hermite	solutions of / solutions de $y''-2xy'+2ny=0$ $H_n(x)=(-1)^n e^{x^2}\frac{d^n}{dx^n}e^{-x^2}$ $(n=0,1,2,\ldots)$
11-11.12	$L_n(x)$	Laguerre polynomials polynômes de Laguerre	solutions of / solutions de $xy''+(1-x)y'+ny=0$ $L_n(x)=e^x\frac{d^n}{dx^n}(x^n e^{-x}) \quad (n=0,1,2,\ldots)$
11-11.13	$L_n^m(x)$	associated Laguerre polynomials polynômes de Laguerre associés	solutions of / solutions de $xy''+(m+1-x)y'+(n-m)y=0$ $L_n^m(x)=\frac{d^m}{dx^m}L_n(x)$ $(m,n=0,1,2,\ldots;\ m\leqslant n)$

11 Special functions (continued) / Fonctions spéciales (suite)

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-11.14	$F(a,b;c;x)$	hypergeometric functions fonctions hypergéométriques	solutions of / solutions de $x(1-x)y''+[c-(a+b+1)x]y'-aby=0$ $F(a,b;c;x)=1+\frac{ab}{c}x+\frac{a(a+1)b(b+1)}{2!\,c(c+1)}x^2+\ldots$
11-11.15	$F(a;c;x)$	confluent hypergeometric functions fonctions hypergéométriques confluentes	solutions of / solutions de $xy''+(c-x)y'-ay=0$ $F(a;c;x)=1+\frac{a}{c}x+\frac{a(a+1)}{2!\,c(c+1)}x^2+\ldots$
11-11.16	$F(k,\varphi)$	(incomplete) elliptic integral of the first kind intégrale elliptique (incomplète) de première espèce	$F(k,\varphi)=\int_0^{\varphi}\frac{d\vartheta}{\sqrt{1-k^2\sin^2\vartheta}}$ $K(k)=F(k,\pi/2)$ is the complete elliptic integral of the first kind est l'intégrale elliptique complète de première espèce
11-11.17	$E(k,\varphi)$	(incomplete) elliptic integral of the second kind intégrale elliptique (incomplète) de deuxième espèce	$E(k,\varphi)=\int_0^{\varphi}\sqrt{1-k^2\sin^2\vartheta}\,d\vartheta$ $E(k)=E(k,\pi/2)$ is the complete elliptic integral of the second kind est l'intégrale elliptique complète de deuxième espèce
11-11.18	$\Pi(k,n,\varphi)$	(incomplete) elliptic integral of the third kind intégrale elliptique (incomplète) de troisième espèce	$\Pi(k,n,\varphi)=\int_0^{\varphi}\frac{d\vartheta}{(1+n\sin^2\vartheta)\sqrt{1-k^2\sin^2\vartheta}}$ $\Pi(k,n,\pi/2)$ is the complete elliptic integral of the third kind est l'intégrale elliptique complète de troisième espèce
11-11.19	$\Gamma(x)$	gamma function fonction gamma	$\Gamma(x)=\int_0^{\infty}t^{x-1}e^{-t}dt$ $\Gamma(n+1)=n! \quad (n=0,1,2,\ldots)$

11 Special functions (concluded) / Fonctions spéciales (fin)

Item No.	Sign, Symbol, Expression Signe, symbole, expression	Meaning Sens	Remarks and Examples Remarques et exemples
11-11.20	$\mathrm{Ei}(x)$	exponential integral exponentielle intégrale	$\mathrm{Ei}(x) = \int_{x}^{\infty} \frac{\mathrm{e}^{-t}}{t}\,\mathrm{d}t$
11-11.21	$\mathrm{erf}(x)$	error function fonction erreur	$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_{0}^{x} \mathrm{e}^{-t^2}\mathrm{d}t$ $\mathrm{erfc}(x) = 1 - \mathrm{erf}(x)$ is called the complementary error function $\mathrm{erfc}(x) = 1 - \mathrm{erf}(x)$ est appelé fonction erreur complémentaire
11-11.22	$\zeta(z)$	Riemann zeta function fonction zêta de Riemann	$\zeta(z) = \frac{1}{1^z} + \frac{1}{2^z} + \frac{1}{3^z} + \ldots,\ \mathrm{Re}\, z > 1$

Dimensionless parameters

Introduction

General remarks

This document, containing a table of *dimensionless parameters*, is part 12 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Special remarks

This document contains a selection of dimensionless parameters and constants used for the description of transport phenomena.

Each recommended symbol for such a quantity consists of two letters. When such a symbol appears as a factor in a product, it is recommended that it be separated from the other symbols by a space, by a multiplication sign or by brackets.

1. Dimensionless parameters : momentum transport

Item No.	Symbol	Name	Definition	Remarks
12-1	Re	Reynolds number	$Re = \frac{\varrho v l}{\eta} = \frac{v l}{\nu}$	
12-2	Eu	Euler number	$Eu = \frac{\Delta p}{\varrho v^2}$	
12-3	Fr	Froude number	$Fr = \frac{v}{\sqrt{lg}}$	Sometimes called Reech number.
12-4	Gr	Grashof number	$Gr = \frac{l^3 g \gamma \Delta\theta}{\nu^2}$	$-\frac{\Delta\varrho}{\varrho} = \gamma\Delta\theta$
12-5	We	Weber number	$We = \frac{\varrho v^2 l}{\sigma}$	
12-6	Ma	Mach number	$Ma = \frac{v}{c}$	
12-7	Kn	Knudsen number	$Kn = \frac{\lambda}{l}$	
12-8	Sr	Strouhal number	$Sr = \frac{lf}{v}$	

2. Dimensionless parameters : transport of heat

Item No.	Symbol	Name	Definition	Remarks
12-9	Fo	Fourier number	$Fo = \frac{\lambda t}{c_p \varrho l^2} = \frac{at}{l^2}$	
12-10	Pe	Péclet number	$Pe = \frac{\varrho c_p v l}{\lambda} = \frac{vl}{a}$	$Pe = Re \cdot Pr$
12-11	Ra	Rayleigh number	$Ra = \frac{l^3 \varrho^2 c_p g \gamma \Delta\theta}{\eta\lambda} = \frac{l^3 g \gamma \Delta\theta}{\nu a}$	$Ra = Gr \cdot Pr$
12-12	Nu	Nusselt number	$Nu = \frac{hl}{\lambda}$	
12-13	St	Stanton number	$St = \frac{h}{\varrho v c_p}$	$St = Nu/Pe$ Sometimes called Margoulis number : Ms. $j = St \cdot Pr^{2/3}$ is called heat transfer factor.

Symbols used in the definitions of section 1

Symbol	Name of quantity	Reference in ISO 31
l	a characteristic length	1-3.1
v	a characteristic velocity	1-9.1
$\Delta\theta$	a characteristic temperature difference	4-2.1
Δp	pressure difference	3-13.1
θ	temperature	4-2.1
ϱ	density (mass density)	3-2.1
η	viscosity (dynamic viscosity)	3-21.1
ν	kinematic viscosity : η/ϱ	3-22.1
σ	surface tension	3-23.1
g	acceleration of free fall	1-10.2
γ	cubic expansion coefficient : $-\frac{1}{\varrho}\left(\frac{\partial\varrho}{\partial\theta}\right)_p$	4-3.2
λ	mean free path	8-37.1
f	a characteristic frequency	2-3.1
c	velocity of sound	7-13.1

Symbols used in the definitions of section 2

Symbol	Name of quantity	Reference in ISO 31
l	a characteristic length	1-3.1
v	a characteristic velocity	1-9.1
t	a characteristic time interval	1-6.1
$\Delta\theta$	a characteristic temperature difference	4-2.1
g	acceleration of free fall	1-10.2
θ	temperature	4-2.1
ϱ	density (mass density)	3-2.1
η	viscosity (dynamic viscosity)	3-21.1
ν	kinematic viscosity : η/ϱ	3-22.1
c_p	specific heat capacity at constant pressure	4-15.2
γ	cubic expansion coefficient : $-\frac{1}{\varrho}\left(\frac{\partial\varrho}{\partial\theta}\right)_p$	4-3.2
λ	thermal conductivity	4-9.1
a	thermal diffusivity : $\lambda/\varrho c_p$	4-13.1
h	coefficient of heat transfer : heat/(time × cross sectional area × temperature difference)	4-10.1

3. Dimensionless parameters : transport of matter in a binary mixture

Item No.	Symbol	Name	Definition	Remarks
12-14	Fo^*	Fourier number for mass transfer	$Fo^* = \frac{Dt}{l^2}$	$Fo^* = Fo/Le$ Compare item 12-9.
12-15	Pe^*	Péclet number for mass transfer	$Pe^* = \frac{vl}{D}$	$Pe^* = Re \cdot Sc = Pe \cdot Le$ Compare item 12-10.
12-16	Gr^*	Grashof number for mass transfer	$Gr^* = \frac{l^3 g \beta \Delta x}{\nu^2}$	Compare item 12-4. $-\frac{\Delta\varrho}{\varrho} = \gamma\Delta\theta + \beta\Delta x$
12-17	Nu^*	Nusselt number for mass transfer	$Nu^* = \frac{kl}{\varrho D}$	Sometimes called Sherwood number : Sh. Compare item 12-12.
12-18	St^*	Stanton number for mass transfer	$St^* = \frac{k}{\varrho v}$	$St^* = Nu^*/Pe^*$ Compare item 12-13. $j_m = St^* \cdot Sc^{2/3}$ is called mass transfer factor.

4. Dimensionless constants of matter

Item No.	Symbol	Name	Definition	Remarks
12-19	Pr	Prandtl number	$Pr = \frac{\eta c_p}{\lambda} = \frac{\nu}{a}$	
12-20	Sc	Schmidt number	$Sc = \frac{\eta}{\varrho D} = \frac{\nu}{D}$	
12-21	Le	Lewis number	$Le = \frac{\lambda}{\varrho c_p D} = \frac{a}{D}$	$Le = Sc/Pr$

Symbols used in the definitions of section 3

Symbol	Name of quantity	Reference in ISO 31
l	a characteristic length	1-3.1
v	a characteristic velocity	1-9.1
t	a characteristic time interval	1-6.1
Δx	a characteristic difference of mole fraction	8-15.1
g	acceleration of free fall	1-10.2
ϱ	density (mass density)	3-2.1
ν	kinematic viscosity : η/ϱ	3-22.1
β	$\beta = -\frac{1}{\varrho}\left(\frac{\partial\varrho}{\partial x}\right)_{T,p}$	—
D	diffusion coefficient	8-38.1
k	mass transfer coefficient : mass/(time × cross sectional area × mole fraction difference)	—
γ	cubic expansion coefficient	4-3.2

Symbols used in the definitions of section 4

Symbol	Name of quantity	Reference in ISO 31
ϱ	density (mass density)	3-2.1
η	viscosity (dynamic viscosity)	3-21.1
ν	kinematic viscosity : η/ϱ	3-22.1
D	diffusion coefficient	8-38.1
c_p	specific heat capacity at constant pressure	4-15.2
λ	thermal conductivity	4-9.1
a	thermal diffusivity : $\lambda/\varrho c_p$	4-13.1

5. Dimensionless parameters : magnetohydrodynamics

Item No.	Symbol	Name	Definition	Remarks
12-22	Rm	magnetic Reynolds number	$Rm = \frac{vl}{1/\mu\sigma} = v\mu\sigma l$	
12-23	Al	Alfvén number	$Al = \frac{v}{v_A}$	$v_A = B/(\varrho\mu)^{1/2}$ is called Alfvén speed.
12-24	Ha	Hartmann number	$Ha = Bl\left(\frac{\sigma}{\varrho\nu}\right)^{1/2}$	
12-25	Co	Cowling number	$Co = \frac{B^2}{\mu\varrho v^2}$	$Co = (v_A/v)^2 = Al^{-2}$ Often called "second" Cowling number : Co_2. The "first" Cowling number is often defined as : $Co_1 = Ha^2/Re = \frac{B^2 l\sigma}{\varrho v} = Co \cdot Rm$

Symbols used in the definitions of section 5

Symbol	Name of quantity	Reference in ISO 31
ϱ	density (mass density)	3-2.1
l	a characteristic length	1-3.1
v	a characteristic velocity	1-9.1
ν	kinematic viscosity : η/ϱ	3-22.1
μ	magnetic permeability	5-24.1
B	magnetic flux density	5-19.1
σ	electric conductivity	5-36.1

Quantities and units of solid state physics

Introduction

This document, containing a table of *quantities and units of solid state physics*, is part 13 of ISO 31, which deals with quantities and units in the various fields of science and technology. The complete list of parts of ISO 31 is as follows :

Part 0 : *General principles concerning quantities, units and symbols.*

Part 1 : *Quantities and units of space and time.*

Part 2 : *Quantities and units of periodic and related phenomena.*

Part 3 : *Quantities and units of mechanics.*

Part 4 : *Quantities and units of heat.*

Part 5 : *Quantities and units of electricity and magnetism.*

Part 6 : *Quantities and units of light and related electromagnetic radiations.*

Part 7 : *Quantities and units of acoustics.*

Part 8 : *Quantities and units of physical chemistry and molecular physics.*

Part 9 : *Quantities and units of atomic and nuclear physics.*

Part 10 : *Quantities and units of nuclear reactions and ionizing radiations.*

Part 11 : *Mathematical signs and symbols for use in the physical sciences and technology.*

Part 12 : *Dimensionless parameters.*

Part 13 : *Quantities and units of solid state physics.*

Arrangement of the tables

The tables of quantities and units in ISO 31 are arranged so that the quantities are presented on left-hand pages and the units on corresponding right-hand pages.

All units between two full lines belong to the quantities between the corresponding full lines on the left-hand pages.

Where the numbering of the items has been changed in the revision of a part of ISO 31, the number in the preceding edition is shown in parentheses on the left-hand page under the new number for the quantity; a dash is used to indicate that the item in question did not appear in the preceding edition.

Tables of quantities

The most important quantities within the field of this document are given together with their symbols and, in most cases, definitions. These definitions are given merely for identification; they are not intended to be complete.

The vectorial character of some quantities is pointed out, especially when this is needed for the definitions, but no attempt is made to be complete or consistent.

In most cases only one symbol for the quantity is given[1]; where two or more symbols are given for one quantity and no special distinction is made, they are on an equal footing. When a preferred symbol and a reserve symbol are given, the reserve symbol is in parentheses.

Tables of units

Units for the corresponding quantities are given together with the international symbols and the definitions. For further information, see also ISO 31/0.

(1) When two types of sloping letters exist (for example as with θ; ϑ; φ; ϕ; g; g) only one of these is given; this does not mean that the other is not equally acceptable.

The units are arranged in the following way :

1) The names of the SI units are given in large print (larger than text size). The SI units and their decimal multiples and sub-multiples formed by means of the SI prefixes are particularly recommended. The decimal multiples and sub-multiples are not explicity mentioned.

2) The names of non-SI units which may be used together with SI units because of their practical importance or because of their use in specialized fields are given in normal print (text size).

3) The names of non-SI units which may be used temporarily together with SI units are given in small print (smaller than text size).

The units in classes 2 and 3 are separated by a broken line from the SI units for the quantities concerned.

4) Non-SI units which should not be used together with SI units are given in annexes in some parts of ISO 31. These annexes are not integral parts of the standards. They are arranged in three groups :

a) *Units of the CGS system with special names*

It is generally preferable not to use the special names and symbols of CGS units together with SI units.

b) *Units based on the foot, pound and second and some other units*

c) *Other units*

These are given for information, especially regarding the conversion factor. The use of those units marked with † is deprecated.

Remark on supplementary units

The General Conference of Weights and Measures has classified the SI units radian and steradian as "supplementary units", deliberately leaving open the question of whether they are base units or derived units, and consequently the question of whether plane angle and solid angle are to be considered as base quantities or derived quantities.[1]

In ISO 31, plane angle and solid angle are treated as derived quantities (see also ISO 31/0). In ISO 31, they are defined as ratios of two lengths and of two areas respectively, and consequently they are treated as dimensionless quantities. Although in this treatment the coherent unit for both quantities is the number 1, it is convenient to use the special names radian and steradian instead of the number 1 in many practical cases.

If plane angle and solid angle were treated as base quantities, the units radian and steradian would be base units and could not be considered as special names for the number 1. Such a treatment would require extensive changes in ISO 31.

Number of digits in numerical statements[2]

All numbers in the column "Definition" are exact.

In the column "Conversion factors", the conversion factors on which the calculation of others is based are normally given to seven significant digits. When they are exact and contain seven or fewer digits, and where it is not obvious from the context, the word "exactly" is added, but when they can be terminated after more than seven digits, they may be given in full. When the conversion factors are derived from experiment, they are given with the number of significant digits justified by the accuracy of the experiments. Generally, this means that in such cases the last digit only is in doubt. When, however, experiment justifies more than seven digits, the factor is usually rounded off to seven significant digits.

The other conversion factors are given to not more than six significant digits; when they are exactly known and contain six or fewer digits, and where it is not obvious from the context, the word "exactly" is added.

Numbers in the column "Remarks" are given to a precision appropriate to the particular case.

(1) However, in October 1980 the International Committee of Weights and Measures decided to interpret the class of supplementary units in the International System as a class of dimensionless derived units for which the General Conference of Weights and Measures leaves open the possibility of using these or not in expressions of derived units of the International System.

(2) The decimal sign is a comma on the line. In documents in the English language, a comma or a dot on the line may be used.

Solid state physics

13. Solid state physics

Quantities
13-1.1 . . . 13-7

Item No.	Quantity	Symbol	Definition	Remarks
13-1.1	lattice vector	$\boldsymbol{R}$, $\boldsymbol{R}_0$, $\boldsymbol{T}$	A translation vector which maps the crystal lattice on itself.	
13-1.2	fundamental lattice vector	$\boldsymbol{a}_1$, $\boldsymbol{a}_2$, $\boldsymbol{a}_3$ $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$	Fundamental translation vectors for the crystal lattice.	$\boldsymbol{R} = n_1\boldsymbol{a}_1 + n_2\boldsymbol{a}_2 + n_3\boldsymbol{a}_3$ where n_1, n_2 and n_3 are integers.
13-2.1	(circular) reciprocal lattice vector	$\boldsymbol{G}$	A vector whose scalar products with all lattice vectors are integral multiples of 2π.	
13-2.2	fundamental reciprocal lattice vectors	$\boldsymbol{b}_1$, $\boldsymbol{b}_2$, $\boldsymbol{b}_3$ $\boldsymbol{a}^*$, $\boldsymbol{b}^*$, $\boldsymbol{c}^*$	The fundamental translation vectors for the reciprocal lattice.	$\boldsymbol{a}_i \cdot \boldsymbol{b}_k = 2\pi\delta_{ik}$ In crystallography, however, $\boldsymbol{a}_i \cdot \boldsymbol{b}_k = \delta_{ik}$ is commonly used.
13-3	lattice plane spacing	d	Distance between successive lattice planes.	
13-4	Bragg angle	θ	$2d \sin\theta = n\lambda$ where λ is the wavelength of the radiation in question and n is an integer.	In ISO 31, plane angle is regarded as dimensionless. See ISO 31/1, 1-1.1 and the introduction.
13-5	order of reflexion	n		This quantity is dimensionless.
13-6.1	short range order parameter	σ	The fraction of nearest neighbour atom pairs in an Ising ferromagnet having parallel magnetic moments minus the fraction having anti-parallel magnetic moments.	These quantities are dimensionless. Similar definitions apply to other order-disorder phenomena.
13-6.2	long range order parameter	s	The fraction of atoms in an Ising ferromagnet having their magnetic moments directed in one direction minus the fraction with magnetic moments in the opposite direction.	
13-7	Burgers vector	$\boldsymbol{b}$	Vector characterizing a dislocation, being the closing vector of a Burgers circuit encircling a dislocation line.	

13. Solid state physics

Units
13-1.a . . . 13-7.b

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-1.a	metre	m			
13-1.b	ångström	Å	1 Å = 10^{-10} m	1 Å = 10^{-10} m (exactly)	1 Å = 0,1 nm The use of the nanometre is recommended.
13-2.a	reciprocal metre, metre to the power minus one	m^{-1}			
13-2.b	reciprocal ångström, ångström to the power minus one	$Å^{-1}$		1 $Å^{-1}$ = 10^{10} m^{-1} (exactly)	1 $Å^{-1}$ = 10 nm^{-1} The use of the reciprocal nanometre is recommended.
13-3.a	metre	m			
13-3.b	ångström	Å			See remark to 13-1.b.
13-4.a	radian	rad			The radian is used here instead of the pure number 1. For other units, see ISO 31/1, 1-1.1.
13-4.b	degree	°		1° = 0,017 453 3 rad	
13-7.a	metre	m			
13-7.b	ångström	Å			See remark to 13-1.b.

Quantities
13-8.1 . . . 13-13

13. Solid state physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
13-8.1	particle position vector	$\boldsymbol{r}$, $\boldsymbol{R}$		To distinguish between electron and ion position vectors, small and capital letters are used, respectively.
13-8.2	equilibrium position vector of ion	$\boldsymbol{R}_0$		
13-8.3	displacement vector of ion	$\boldsymbol{u}$	$\boldsymbol{u} = \boldsymbol{R} - \boldsymbol{R}_0$	
13-9	Debye-Waller factor	D	Factor by which the intensity of a diffraction line is reduced because of lattice vibrations.	This quantity is dimensionless. It is sometimes expressed as $\exp(-2W)$; in Mössbauer spectroscopy it is also called f-factor and denoted by f.
13-10.1	circular wavenumber	k, q	$k = 2\pi/\lambda$ where λ is the wavelength.	The corresponding vector quantity $\boldsymbol{k}$ or $\boldsymbol{q}$ is called the propagation vector. When a distinction is needed between k and the symbol for the Boltzmann constant, k_B can be used for the latter. When a distinction is needed between k and q, q should be used for phonons and magnons, k for particles like electrons and neutrons.
13-10.2	Fermi circular wavenumber	k_F	Circular wave number of electrons in states on the Fermi sphere.	
13-10.3	Debye circular wavenumber	q_D	Cut-off circular wave number in the Debye model of the vibrational spectrum of a solid.	The methods of cut-off must be specified.
13-11	Debye circular frequency	ω_D	Cut-off circular frequency in the Debye model of the vibrational spectrum of a solid.	The method of cut-off must be specified.
13-12	Debye temperature	Θ_D	$k\,\Theta_D = \hbar\,\omega_D$ where k is the Boltzmann constant and $\hbar$ is the Planck constant divided by 2π.	k = (1,380 662 ± 0,000 044) × 10^{-23} J/K(1) $\hbar$ = (1,054 588 7 ± 0,000 005 7) × 10^{-34} J·s(1)
13-13	spectral concentration of vibrational modes (in terms of circular frequency)	g, N_ω	The number of vibrational modes in an infinitesimal interval of circular frequency, divided by the range of that interval and by volume.	$g(\omega) = N_\omega(\omega) = \dfrac{\mathrm{d}N(\omega)}{\mathrm{d}\,\omega}$ where $N(\omega)$ is the total number of vibration modes with circular frequency less than ω, divided by volume.

(1) CODATA Bulletin 11 (1973).

13. Solid state physics (continued)

Units
13-8.a . . . 13-13.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-8.a	metre	m			
13-10.a	reciprocal metre, metre to the power minus one	m^{-1}			
13-10.b	reciprocal ångström, ångström to the power minus one	$Å^{-1}$			See remark to 13-2.b.
13-11.a	reciprocal second, second to the power minus one	s^{-1}			
13-12.a	kelvin	K			
13-13.a	second per cubic metre	s/m^3			

Quantities
13-14 . . . 13-19

13. Solid state physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
13-14	Grüneisen parameter	γ, Γ	$\gamma = \alpha_V / (\kappa\, c_V\, \varrho)$ where α_V is the cubic expansion coefficient, κ is the isothermal compressibility, c_V is the specific heat capacity at constant volume and ϱ is the mass density.	This quantity is dimensionless.
13-15	Madelung constant	α	For a uni-univalent ionic crystal of specified structure, the electrostatic energy per pair of ions is $\alpha \cdot \frac{e^2}{4\pi\,\epsilon_0\, a}$ where e is the elementary charge, ϵ_0 is the permittivity of vacuum and a is a lattice constant which should be specified.	This quantity is dimensionless.
13-16.1	mean free path of phonons	l_{ph}, Λ		
13-16.2	mean free path of electrons	l, l_e		
13-17	density of states	N_E, ϱ	The number of one-electron states in an infinitesimal interval of energy, divided by the range of that interval and by volume.	$\varrho(E) = N(E) = \frac{\mathrm{d}N(E)}{\mathrm{d}(E)}$ where $N(E)$ is the total number of electron states with energy less than E, divided by volume.
13-18	residual resistivity	ϱ_R	For metals, the extrapolated resistivity at zero thermodynamic temperature.	
13-19	Lorenz coefficient	L	$L = \lambda / \sigma T$ where λ is the thermal conductivity, σ is the electric conductivity and T is the thermodynamic temperature.	

13. Solid state physics (continued)

Units
13-16.a . . . 13-19.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-16.a	metre	m			
13-17.a	reciprocal joule reciprocal cubic metre, joule to the power minus one metre to the power minus three	$J^{-1}.m^{-3}$			
13-17.b	reciprocal electronvolt reciprocal cubic metre, electronvolt to the power minus one metre to the power minus three	$eV^{-1}.m^{-3}$		1 $eV^{-1}.m^{-3}$ = 6,241 46 × 10^{18} $J^{-1}.m^{-3}$	See ISO 31/3, 3-24.c.
13-18.a	ohm metre	Ω.m			
13-19.a	volt squared per kelvin squared	V^2/K^2			

13. Solid state physics (continued)

Quantities
13-20 . . . 13-26

Item No.	Quantity	Symbol	Definition	Remarks
13-20	Hall coefficient	A_H, R_H	In an isotropic conductor, the relation between electric field strength $\boldsymbol{E}$ and current density $\boldsymbol{J}$ is $\boldsymbol{E} = \varrho \boldsymbol{J} + R_H (\boldsymbol{B} \times \boldsymbol{J})$ where ϱ is the resistivity and $\boldsymbol{B}$ is the magnetic flux density.	
13-21	thermoelectromotive force between substances a and b	E_{ab}		The positive direction for E_{ab} is from substance a to substance b at the cold junction.
13-22	Seebeck coefficient for substances a and b	S_{ab}, ϵ_{ab}	$S_{ab} = \frac{dE_{ab}}{dT}$ where T is the temperature of the hot junction.	$S_{ab} = S_a - S_b$ where S_a is the Seebeck coefficient of substance a.
13-23	Peltier coefficient for substances a and b	Π_{ab}	Peltier heat power developed at a junction divided by electric current from substance a to substance b.	$\Pi_{ab} = \Pi_a - \Pi_b$ where Π_a is the Peltier coefficient of substance a.
13-24	Thomson coefficient	μ, τ	Thomson heat power developed divided by electric current and temperature difference.	μ is positive if heat is developed when the temperature decreases in the direction of the electric current.
13-25	work function	Φ	Energy difference between an electron at rest at infinity and an electron at the Fermi level in the interior of a substance.	The contact potential difference between substances a and b is $V_a - V_b = (\Phi_b - \Phi_a)/e$ where e is the elementary charge.
13-26	Richardson constant	A	The thermionic emission current density J from a metal is $J = AT^2 \exp(-\Phi/kT)$ where T is the thermodynamic temperature, k is the Boltzmann constant and Φ is the work function.	

13. Solid state physics (continued)

Units
13-20.a . . . 13-26.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-20.a	cubic metre per coulomb	m^3/C			
13-21.a	volt	V			
13-22.a	volt per kelvin	V/K			
13-23.a	volt	V			
13-24.a	volt per kelvin	V/K			
13-25.a	joule	J			
13-25.b	electronvolt	eV		1 eV = 1,602 189 2 $\times 10^{-19}$ J	
13-26.a	ampere per square metre kelvin squared	$A/(m^2 K^2)$			

Quantities
13-27.1 . . . 13-31

13. Solid state physics (continued)

Item No.	Quantity	Symbol	Definition	Remarks
13-27.1	Fermi energy	E_F, ϵ_F	In a metal, the highest energy of occupied states at zero thermodynamic temperature.	At $T = 0$, E_F is equal to the chemical potential per electron.
13-27.2	gap energy	E_g	Difference in energy between lowest level of conduction band and highest level of valence band.	
13-27.3	donor ionization energy	E_d		
13-27.4	acceptor ionization energy	E_a		
13-28	Fermi temperature	T_F	$T_F = E_F / k$ where k is the Boltzmann constant.	
13-29.1	electron number density	n, n_n, n_-	Number density of electrons in conduction band.	In general, subscripts n and p or − and + are used to denote electrons and holes, respectively.
13-29.2	hole number density	p, n_p, n_+	Number density of holes in valence band.	n_n and n_p are also used for electron number densities in n-type and p-type regions of a $p-n$ junction, respectively.
13-29.3	intrinsic number density	n_i	$n\,p = n_i^2$	
13-29.4	donor number density	n_d, N_d	Number density of donor levels.	
13-29.5	acceptor number density	n_a, N_a	Number density of acceptor levels.	
13-30	effective mass	m^*		m_n^* and m_p^* for electrons and holes in semiconductors.
13-31	mobility ratio	b	$b = \mu_n / \mu_p$ where μ_n and μ_p are the mobilities of electrons and holes respectively.	This quantity is dimensionless. For mobility, see ISO 31/10, 10-26.1.

13. Solid state physics (continued)

Units
13-27.a . . . 13-30.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-27.a	joule	J			
13-27.b	electronvolt	eV		1 eV = 1,602 189 2 × 10^{-19} J	
13-28.a	kelvin	K			
13-29.a	reciprocal cubic metre, metre to the power minus three	m^{-3}			
13-30.a	kilogram	kg			

13. Solid state physics (continued)

Quantities
13-32.1 . . . 13-36.3

Item No.	Quantity	Symbol	Definition	Remarks
13-32.1	relaxation time	τ	Time constant for exponential decay towards equilibrium.	For electrons in metals, $\tau = l/v_F$ where l is the mean free path and v_F is the velocity of electrons on the Fermi sphere.
13-32.2	carrier life time	τ, τ_n, τ_p	Time constant for recombination or trapping of minority charge carriers in semiconductors.	See remark to 13-29.1.
13-33	diffusion length	L, L_n, L_p	$L = \sqrt{D\tau}$ where D is the diffusion coefficient and τ is the life time.	See remark to 13-29.1. For D, see ISO 31/8, 8-38.1.
13-34	exchange integral	J	Interaction energy arising from electron exchange.	
13-35.1	Curie temperature	T_C	Critical temperature of a ferromagnet.	T_C (or, in case of ambiguity, T_{Cf}) is used for critical temperature in general.
13-35.2	Néel temperature	T_N	Critical temperature of an antiferromagnet.	
13-35.3	superconductor transition temperature	T_c	Critical temperature of a superconductor.	
13-36.1	thermodynamic critical field strength	H_c	$G_n - G_s = \frac{1}{2}\mu_0 H_c^2 \cdot V$ where G_n and G_s are the Gibbs free energies at zero magnetic field of normal conductor and superconductor respectively, μ_0 is the permeability of vacuum and V is the volume.	In type I superconductors, H_c is the critical field strength for disappearance of superconductivity.
13-36.2	lower critical field strength	H_{c1}	For type II superconductors, the threshold magnetic field strength for magnetic flux entering the superconductor.	The symbol H_{c3} is used for the critical field strength for disappearance of surface superconductivity.
13-36.3	upper critical field strength	H_{c2}	For type II superconductors, the threshold magnetic strength for disappearance of bulk superconductivity.	For the corresponding Gaussian quantities, see ISO 31/5, annex A.

13. Solid state physics (continued)

Units
13-32.a . . . 13-36.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-32.a	second	s			
13-33.a	metre	m			
13-34.a	joule	J			
13-34.b	electronvolt	eV		1 eV = 1,602 189 2 $\times 10^{-19}$ J	
13-35.a	kelvin	K			
13-36.a	ampere per metre	A/m			For the Gaussian CGS unit of magnetic field strength, oersted, see ISO 31/5, annex A.

13. Solid state physics (concluded)

Quantities
13-37 . . . 13-40

Item No.	Quantity	Symbol	Definition	Remarks
13-37	superconductor energy gap parameter	Δ		
13-38.1	London penetration depth	λ_L	If an applied magnetic field is parallel to the plane surface of a semi-infinite superconductor, the field penetrates the superconductor according to the expression $H(x) = H(0) \exp(-x/\lambda_L)$	
13-38.2	coherence length	ξ	The distance in a superconductor over which the effect of a perturbation is appreciable.	
13-39	Landau-Ginzburg parameter	κ	$\kappa = \lambda_L/(\xi\sqrt{2})$ at $T = 0$	This quantity is dimensionless.
13-40	fluxoid quantum	Φ_0	$\Phi_0 = h/2e$	$\Phi_0 = (2{,}067\,850\,6 \pm 0{,}000\,005\,4) \times 10^{-15}$ Wb[1].

(1) CODATA Bulletin 11 (1973).

13. Solid state physics (concluded)

Units
13-37.a . . . 13-40.a

Item No.	Name of unit	International symbol for unit	Definition	Conversion factors	Remarks
13-37.a	joule	J			
13-37.b	electronvolt	eV		1 eV = 1,602 189 2 $\times 10^{-19}$ J	
13-38.a	metre	m			
13-40.a	weber	Wb	1 Wb = 1 V·s		For the Gaussian CGS unit of magnetic flux, maxwell, see ISO 31/5, annex A.

Annex

Symbols for planes and directions in crystals

Miller indices	h_1, h_2, h_3 or h, k, l
Single plane or set of parallel planes in lattice	(h_1, h_2, h_3) or (h, k, l)
Full set of planes in lattice equivalent by symmetry	$\{h_1, h_2, h_3\}$ or $\{h, k, l\}$
Direction in lattice	$[u, v, w]$
Full set of directions in lattice equivalent by symmetry	$< u, v, w >$

NOTES

1 If the letter symbols are replaced by numbers in the bracketed expressions, it is customary to omit the commas.

2 A negative numerical value of h, k or l is commonly indicated by a bar above the number, for example $(\bar{1}10)$.

INDEX OF NAMES OF PHYSICAL QUANTITIES (WITH THEIR SYMBOLS) IN THE ISO 31 SERIES

The names of the physical quantities (and their symbols) in this index are in accordance with the following editions of the various parts of ISO 31 :

ISO 31/1, *Quantities and units of space and time* (first edition — 1978-03-15)

ISO 31/2, *Quantities and units of periodic and related phenomena* (first edition — 1978-03-15)

ISO 31/3, *Quantities and units of mechanics* (first edition — 1978-03-15)

ISO 31/4, *Quantities and units of heat* (first edition — 1978-03-15)

ISO 31/5, *Quantities and units of electricity and magnetism* (first edition — 1979-02-15)

ISO 31/6, *Quantities and units of light and related electromagnetic radiations* (second edition — 1980-12-15)

ISO 31/7, *Quantities and units of acoustics* (first edition — 1978-03-15)

ISO 31/8, *Quantities and units of physical chemistry and molecular physics* (second edition — 1980-12-15)

ISO 31/9, *Quantities and units of atomic and nuclear physics* (second edition — 1980-12-15)

ISO 31/10, *Quantities and units of nuclear reactions and ionizing radiations* (second edition — 1980-12-15)

ISO 31/13, *Quantities and units of solid state physics* (second edition — 1981-07-15)

Explication to the symbol(s) column

When more than one symbol for a physical quantity is given in the symbol(s) column, these are on equal footing. However, this does not apply to the cases where a reserve symbol is given in parentheses. A reserve symbol should be used only when the use of the preceding symbol(s) would result in duplication of symbols for two different physical quantities in one context.

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
A		
absolute activity of substance B	λ_B	8-18.1
absorbed dose	D	10-51.1
absorbed dose rate	$\dot{D}$	10-53.1
acceleration	a	1-10.1
acceleration of free fall, acceleration due to gravity	g	1-10.2
acceptor ionization energy	E_a	13-27.4
acceptor number density	n_a, N_a	13-29.5
acoustic absorption coefficient	α, (α_a)	7-26.4
acoustic impedance	Z_a	7-18.1
activity	A	9-33.1 10-49.1
activity coefficient of substance B (in a liquid or a solid mixture)	f_B	8-22.1
activity coefficient of solute substance B (especially in a dilute liquid solution)	γ_B	8-24.1
activity of solute substance B, relative activity of solute substance B (especially in a dilute liquid solution)	a_B, $a_{m,B}$	8-23.1
activity of solvent substance A, relative activity of solvent substance A (especially in a dilute liquid solution)	a_A	8-25.1
admittance, (complex admittance)	Y	5-43.1
(admittance), modulus of admittance	$\|Y\|$	5-43.2
affinity (of a chemical reaction)	A	8-28.1
alpha disintegration energy	Q_α	9-37.1
amount of substance	n, (ν)	8-3.1
amount-of-substance concentration of substance B, concentration of substance B	c_B	8-13.1
amplitude level difference, field level difference	L_F	2-7.1
angle, (plane angle)	α, β, γ, ϑ, φ, etc.	1-1.1
angular acceleration	α	1-8.1
angular cross section	σ_Ω	10-4.1
angular frequency, circular frequency, pulsatance	ω	2-4.1 6-2.1 7-4.1
angular momentum, moment of momentum	L	3-8.1
angular velocity	ω	1-7.1

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
area	A, (S)	1-4.1
atomic attenuation coefficient	μ_a, μ_{at}	10-16.1
atomic number, proton number	Z	8-41.1 9-1.1
atomic mass constant (unified)	m_u	9-4.2
attenuation coefficient	α	2-11.1 7-25.1
average energy loss per ion pair formed (average energy loss per elementary charge of one sign produced)	W_i	10-25.1
average logarithmic energy decrement	ξ	10-38.1
Avogadro constant	L, N_A	8-4.1
B		
beta disintegration energy	Q_β	9-39.1
beta maximum energy	E_β	9-37.1
binding fraction	b	9-30.2
Bohr magneton	μ_B	9-11.2
Bohr radius	a_o	9-8.1
Boltzmann constant	k	8-36.1
Bragg angle	θ	13-4
breadth	b	1-3.2
bulk compressibility, compressibility	κ	3-17.1
bulk modulus, modulus of compression	K	3-16.3
(bulk strain), volume strain	ϑ	3-14.3
Burgers vector	$\boldsymbol{b}$	13-7
C		
canonical partition function	Q, Z	8-33.2
capacitance	C	5-9.1
carrier life time	τ, τ_n, τ_p	13-32.2
Celsius temperature	t, ϑ	4-2.1
characteristic impedance of a medium	Z_c	7-17.1
charge density, volume density of charge	ϱ, (η)	5-3.1
charge number of ion	z	8-43.1
chemical potential of substance B	μ_B	8-17.1

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
chromaticity coordinates	x, y, z	6-29.1
CIE spectral tristimulus values	$\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$	6-28.1
circular frequency	ω	6-2.1
circular frequency, pulsatance, angular frequency	ω	2-4.1 7-4.1
(circular) reciprocal lattice vector	$\boldsymbol{G}$	13-2.1
circular repetency, circular wavenumber	k	6-4.2
circular wavenumber	k	2-6.2 6-4.2 7-6.1
	k, q	13-10.1
coefficient of friction, friction factor	$\mu, (f)$	3-20.1
coefficient of heat transfer	h, k, K, α	4-10.1
coefficient of thermal insulation, thermal insulance	M	4-11.1
coherence length	ξ	13-38.2
(complex admittance), admittance	Y	5-43.1
(complex impedance), impedance	Z	5-41.1
compressibility, bulk compressibility	κ	4-5.1 3-17.1
Compton wavelength	λ_C	9-27.1
concentration of substance B, amount-of-substance concentration of substance B	c_B	8-13.1
conductance	G	5-43.4
conductance (to direct current)	G	5-34.1
conductivity	γ, σ	5-36.1
coupling coefficient	$k, (\kappa)$	5-23.1
cross section	σ	10-3.1
cross section density, macroscopic cross section	Σ	10-7.1
cubic expansion coefficient	α_V, γ	4-3.2
Curie temperature	T_C	13-35.1
current density	$J, (S)$	5-15.1
current density of particles	$J, (S)$	10-12.1
current fraction of ionic substance B, transport number of ionic substance B	t_B	8-49.1

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
current linkage	Θ	5-18.3
cyclotron angular frequency, cycloton circular frequency	ω_c	9-15.1
D		
damping coefficient	δ	2-9.1 7-22.1
Debye circular frequency	ω_D	13-11
Debye circular wavenumber	q_D	13-10.3
Debye temperature	Θ_D	13-12
Debye-Waller factor	D	13-9
decay constant, disintegration constant	λ	9-35.1
degree of dissociation	α	8-46.1
density (mass density)	ϱ	3-2.1 7-7.1 8-11.1
density of heat flow rate	q, φ	4-8.1
density of states	N_E, ϱ	13-17
diameter	d, D	1-3.6
diffusion area	L^2	10-40.2
diffusion coefficient	D	8-38.1
diffusion coefficient, diffusion coefficient for neutron number density	D, D_n	10-32.1
diffusion coefficient for neutron fluence rate, diffusion coefficient for neutron flux density	$D_\varphi, (D)$	10-33.1
diffusion length	L	10-41.2
	L, L_n, L_p	13-33
directional spectral emissivity	$\varepsilon(\lambda, \vartheta, \varphi)$	6-18.3
disintegration constant, decay constant	λ	9-35.1
displacement, electric flux density	D	5-7.1
displacement vector of ion	$\mathbf{u}$	13-8.3
dissipation coefficient	$\delta, (\psi)$	7-26.1
donor ionization energy	E_d	13-27.3
donor number density	n_d, N_d	13-29.4
dose equivalent	H	10-52.1
duration, time, time interval	t	1-6.1

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
(dynamic moment of inertia), moment of inertia	I, J	3-9.1
(dynamic viscosity), viscosity	η, (μ)	3-21.1
E		
effective mass	m^*	13-30
effective multiplication factor	k_{eff}	10-46.3
electric charge, quantity of electricity	Q	5-2.1
electric constant, permittivity of vacuum	ε_0	5-10.2
electric current	I	5-1.1
electric dipole moment	p, (p_e)	5-14.1
electric dipole moment of molecule	p, μ	8-31.1
electric field strength	E, (K)	5-5.1
electric flux, (flux of displacement)	Ψ	5-8.1
electric flux density, displacement	D	5-7.1
electric polarization	P	5-13.1
electric polarizability of a molecule	α	8-32.1
electric potential	V, φ	5-6.1
electric susceptibility	χ, χ_e	5-12.1
electrolytic conductivity	κ, σ	8-47.1
electromagnetic energy density	w	5-30.1
electromagnetic moment, (magnetic moment)	m	5-27.1
electromotive force	E	5-6.3
electron number density	n, n_0, n_-	13-29.1
electron radius	r_e	9-26.1
elementary charge	e	8-42.1 9-6.1
emissivity	ε	6-18.1
emissivity at a specified wavelength, spectral emissivity	$\varepsilon(\lambda)$	6-18.2
energy	E, (W)	3-24.2
energy fluence	Ψ	10-10.1
energy fluence rate, energy flux density	ψ	10-11.1
energy imparted	ε	10-50.1
enthalpy	H, (I)	4-19.2

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
entropy	S	4-17.1
equilibrium position vector of ion	$\boldsymbol{R}_0$	13-8.2
equivalent absorption area of a surface or object	A	7-28.1
exchange integral	J	13-34
exposure	X	10-58.1
exposure rate	$\dot{X}$	10-59.1
F		
Faraday constant	F	8-44.1
fast fission factor	ε	10-43.1
Fermi circular wavenumber	k_F	13-10.2
Fermi energy	E_F, ϵ_F	13-27.1
Fermi temperature	T_F	13-28
field level difference, amplitude level difference	L_f	2-7.1
fine-structure constant	α	9-25.1
first radiation constant	c_1	6-16.1
(flux of displacement), electric flux	Ψ	5-8.1
fluxoid quantum	Φ_0	13-40
force	F	3-10.1
frequency	f, ν	2-3.1 6-1.1 7-2.1
frequency interval	—	7-3.1
friction factor, coefficient of friction	μ, (f)	3-20.1
fugacity of substance B (in a gaseous mixture)	f_B, $\tilde{p}_B$	8-20.1
fundamental lattice vector	$\boldsymbol{a}_1$, $\boldsymbol{a}_2$, $\boldsymbol{a}_3$ $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$	13-1.2
fundamental reciprocal lattice vectors	$\boldsymbol{b}_1$, $\boldsymbol{b}_2$, $\boldsymbol{b}_3$ $\boldsymbol{a}^*$, $\boldsymbol{b}^*$, $\boldsymbol{c}^*$	13-2.2
G		
gap energy	E_g	13-27.2
g-factor of atom or electron	g	9-13.1
g-factor of nucleus or nuclear particle	g	9-13.2
Gibbs free energy, Gibbs function	G	4-19.4

NAME OF QUANTITY	SYMBOL(S)	ITEM NUMBER
grand-canonical partition function, grand partition function	Ξ	8-33.3
gravitational constant	G, (f)	3-11.1
Grüneisen parameter	γ, Γ	13-14
gyromagnetic coefficient, (gyromagnetic ratio)	γ	9-12.1
H		
half-thickness, half value thickness	$d_{1\,2}$	10-17.1
half-life	$T_{1/2}$	9-36.1
Hall coefficient	A_H, R_H	13-20
Hartree energy	E_h	9-10.1
heat, quantity of heat	Q	4-6.1
heat capacity	C	4-14.1
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hole number density	p, n_p, n_+	13-29.2
hyperfine structure quantum number	F	9-22.1
I		
illuminance	E, (E_v)	6-24.1
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ion density, ion number density	n^+, n^-	10-27.1
ionic strength	I	8-45.1
irradiance	E, (E_e)	6-14.1
isentropic exponent	κ	4-16.2
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kerma	K	10-55.1
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Landau-Ginzburg parameter	κ	13-39
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leakage coefficient	σ	5-23.2
length	l, (L)	1-3.1
length of path	s	1-3.7
lethargy	u	10-37.1
level width	Γ	9-32.1
light exposure	H	6-25.1
linear absorption coefficient	a	6-31.2
linear attenuation coefficient	μ, μ_l	10-13.1
linear attenuation coefficient, linear extinction coefficient	μ, μ_l	6-31.1
linear current density	A, (α)	5-16.1
linear density	ϱ_l	3-5.1
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linear expansion coefficient	α_l	4-3.1
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logarithmic decrement	Λ	2-10.1 7-24.1
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Lorenz coefficient	L	13-19
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luminous efficiency at a specified wavelength, spectral luminous efficiency	$V(\lambda)$	6-27.2
luminous exitance	M, (M_v)	6-23.1
luminous flux	Φ, (Φ_v)	6-20.1
luminous intensity	I, (I_v)	6-19.1
M		
macroscopic cross section, cross section density	Σ	10-7.1
Madelung constant	α	13-15
magnetic constant, permeability of vacuum	μ_0	5-24.2
magnetic field strength	H	5-17.1
magnetic flux	Φ	5-20.1
magnetic flux density, magnetic induction	B	5-19.1
(magnetic moment), electromagnetic moment	m	5-27.1
magnetic moment of particle or nucleus	μ	9-11.1
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magnetic potential difference	U_m	5-18.1
magnetic quantum number	m_l, M	9-24.1
magnetic susceptibility	κ, (χ_m)	5-26.1
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magnetomotive force	F, F_m	5-18.2
mass	m	3-1.1
mass attenuation coefficient	μ/ϱ, μ_m	10-14.1
mass concentration of substance B	ϱ_B	8-11.2
mass defect	B	9-28.2
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mass energy transfer coefficient	μ_{tr}/ϱ	10-57.1
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mass number, nucleon number	A	9-3.1
mass of atom (of a nuclide X), nuclidic mass	m_a, $m(X)$	9-4.1
mass, (rest), of electron	m_e	9-5.1
mass of molecule	m	8-30.1
mass, (rest), of neutron	m_n	9-5.3
mass, (rest), of proton	m_p	9-5.2
Massieu function	J	4-21.1
maximum spectral luminous efficacy	K_m	6-26.3
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mean free path of electrons	l, l_e	13-16.2
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mean life	τ	9-31.1
mean linear range	R, R_l	10-21.1
mean mass range	R_ϱ, (R_m)	10-22.1
mechanical impedance	Z_m	7-19.1
microcanonical partition function	Ω	8-33.1
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molality of solute substance B	b_B, m_B	8-16.1
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molar entropy	S_m	8-9.1
molar gas constant	R	8-35.1
molar heat capacity	C_m	8-8.1
molar internal energy	U_m, (E_m)	8-7.1
molar mass	M	8-5.1
molar volume	V_m	8-6.1
mole fraction of substance B	x_B, (y_B)	8-15.1
mole ratio of solute substance B	r_B	8-15.2
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molecular partition function, partition function of a molecule	q	8-33.4
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N		
Néel temperature	T_N	13-35.2
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neutron number	N	9-2.1
neutron number density	n	10-29.1
neutron speed	v	10-30.1
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neutron yield per fission	ν	10-42.1
non-leakage probability	Λ	10-45.1
normal stress	σ	3-13.2
nuclear magneton	μ_N	9-11.3
nuclear precession angular frequency, nuclear precession circular frequency	ω_N	9-14.2
nuclear quadrupole moment	Q	9-16.1

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nuclear spin quantum number	I	9-21.1
nucleon number, mass number	A	9-3.1
nuclidic mass, mass of atom (of a nuclide X)	m_a, $m(X)$	9-4.1
number density of molecules (or particles)	n	8-10.1
number of molecules or other elementary entities	N	8-2.1
number of pairs of poles	p	5-39.3
number of phases	m	5-39.2
number of turns in a winding	N	5-39.1
O		
orbital angular momentum quantum number	l, L	9-18.1
order of reflexion	n	13-5
osmotic coefficient of the solvent substance A (especially in a dilute liquid solution)	φ	8-25.2
osmotic pressure	Π	8-26.1
P		
packing fraction	f	9-30.1
partial pressure of substance B (in a gaseous mixture)	p_B	8-19.1
particle fluence	Φ	10-8.1
particle fluence rate, particle flux density	φ	10-9.1
particle position vector	$\mathbf{r}$, $\mathbf{R}$	13-8.1
partition function of a molecule, molecular partition function	q	8-33.4
Peltier coefficient for substances a and b	Π_{ab}	13-23
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permeability	μ	5-24.1
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permeance	Λ, (P)	5-38.1
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permittivity of vacuum, electric constant	ε_0	5-10.2
phase coefficient	β	2-11.2 7-25.2
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Planck constant	h	9-7.1
Planck function	Y	4-22.2
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Poisson ratio, Poisson number	μ, ν	3-15.1
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Poynting vector	S	5-31.1
pressure	p	3-13.1
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propagation coefficient	γ	2-11.3 7-25.3
proton number, atomic number	Z	9-1.1 8-41.1
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Q		
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quantity of electricity, electric charge	Q	5-2.1
quantity of heat, heat	Q	4-6.1
quantity of light	$Q, (Q_v)$	6-21.1
R		
radiance	$L, (L_e)$	6-12.1
radiant energy	$Q, W, (U, Q_e)$	6-6.1
radiant energy density	$w, (u)$	6-7.1
radiant energy fluence rate	φ, ψ	6-10.1
radiant energy flux, radiant power	$P, \Phi, (\Phi_e)$	6-9.1
radiant exitance	$M, (M_e)$	6-13.1
radiant intensity	$I, (I_e)$	6-11.1
radiant power, radiant energy flux	$P, \Phi(\Phi_e)$	6-9.1

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radius	r	1-3.5
ratio of the specific heat capacities	γ	4-16.1
reactance	X	5-41.3
reaction energy	Q	10-1.1
reactivity	ϱ	10-47.1
reactor time constant	T	10-48.1
reciprocal lattice vector (circular)	$\boldsymbol{G}$	13-2.1
recombination coefficient	α	10-28.1
reflection coefficient	r, ϱ	7-26.2
refractive index	n	6-33.1
relative activity of solute substance B (especially in a dilute liquid solution), activity of solute subtance B	$a_B, a_{m,B}$	8-23.1
relative activity of solvent substance A (especially in a dilute liquid solution), activity of solvent substance A	a_A	8-25.1
relative atomic mass of an element	A_r	8-1.1
relative density	d	3-3.1
(relative elongation), linear strain	e, ε	3-14.1
relative mass defect	B_r	9-29.2
relative mass excess	Δ_r	9-29.1
relative molecular mass of a substance	M_r	8-1.2
relative permeability	μ_r	5-25.1
relative permittivity	ε_r	5-11.1
relative pressure coefficient	α_p	4-3.3
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resistance (to direct current)	R	5-33.1
resistivity	ϱ	5-35.1
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resonance escape probability	p	10-36.1

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(rest) mass of electron	m_e	9-5.1
(rest) mass of neutron	m_n	9-5.3
(rest) mass of proton	m_p	9-5.2
reverberation time	T	7-29.1
Richardson constant	A	13-26
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S		
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second radiation constant	c_2	6-17.1
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Seebeck coefficient for substances a and b	S_{ab}, ϵ_{ab}	13-22
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shear strain	γ	3-14.2
shear stress	τ	3-13.3
short range order parameter	σ	13-6.1
slowing-down area	L_s^2, L_{sl}^2	10-40.1
slowing-down density	q	10-35.1
slowing-down length	L_s, L_{sl}	10-41.1
solid angle	Ω	1-2.1
sound energy density	w, (w_a, E)	7-14.1
sound energy flux, sound power	P, (P_a)	7-15.1
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sound particle acceleration (instantaneous)	a	7-11.1
sound particle displacement (instantaneous)	ξ, (x)	7-9.1
sound particle velocity (instantaneous)	u, v	7-10.1
sound power, sound energy flux	P, (P_a)	7-15.1
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sound pressure level	L_p	7-20.1
sound reduction index, sound transmission loss	R	7-27.1
specific acoustic impedance	Z_s	7-17.2
specific activity in a sample	a	9-34.1
specific energy imparted	z	10-51.1
specific enthalpy	h, (l)	4-20.2
specific entropy	s	4-18.1
specific Gibbs free energy, specific Gibbs function	g	4-20.4
specific heat capacity	c	4-15.1
specific heat capacity at constant pressure	c_p	4-15.2
specific heat capacity at constant volume	c_v	4-15.3
specific heat capacity at saturation	c_{sat}	4-15.4
specific Helmholtz free energy, specific Helmholtz function	a, f	4-20.3
specific internal energy	u, (e)	4-20.1
specific volume	v	3-4.1
spectral absorption factor, spectral absorptance	$\alpha(\lambda)$	6-30.1
spectral angular cross section	$\sigma_{\Omega,L}$	10-6.1
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spectral concentration of vibrational modes (in terms of circular frequency)	g, N_ω	13-13
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spectral luminous efficacy, luminous efficacy at a specified wavelength	$K(\lambda)$	6-26.2
spectral luminous efficiency, luminous efficiency at a specified wavelength	$V(\lambda)$	6-27.2
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spectral radiant evergy density (in terms of wavelength), spectral concentration of radiant energy density (in terms of wavelength)	w_λ	6-8.1
spectral reflection factor, spectral reflectance	$\varrho(\lambda)$	6-30.2
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spin angular momentum quantum number	s_i, S	9-19.1

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standard absolute activity of solute substance B (especially in a dilute liquid solution)	$\lambda_B^{\prime\prime}$	8-24.2
standard absolute activity of solvent substance A (especially in a dilute liquid solution)	$\lambda_A^{\prime\prime}$	8-25.3
standard absolute activity of substance B (in a gaseous mixture)	$\lambda_B^{\prime\prime}$	8-21.1
standard absolute activity of substance B (in a liquid or solid mixture)	$\lambda_B^{\prime\prime}$	8-22.2
standard equilibrium constant	$K^{\prime\prime}$	8-29.1
static pressure	p_s	7-8.1
statistical weight	g	8-34.1
Stefan-Boltzman constant	σ	6-15.1
stoichiometric number of substance B	ν_B	8-25.1
superconductor energy gap parameter	Δ	13-27
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surface density	ϱ_A, (ϱ_S)	3-6.1
surface density of charge	σ	5-4.1
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T		
tension, potential difference	U, (V)	5-6.2
thermal conductivity	λ, (k)	4-9.1
thermal diffusion coefficient	D_T	8-40.1
thermal diffusion factor	α_T	8-39.2
thermal diffusion ratio	k_T	8-39.1
thermal diffusivity	a, (α, κ)	4-13.1
thermal insulance, coefficient of thermal insulation	M	4-11.1
thermal resistance	R	4-12.1
thermal utilization factor	f	10-44.1
thermodynamic critical field strength	H_c	13-36.1
thermodynamic temperature	T, Θ	4-1.1
thermoelectromotive force between substances a and b	E_{ab}	13-21
thickness	d, δ	1-3.4
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time constant, relaxation time	τ	7-23.1 13-32.1
time constant of an exponentially varying quantity	τ, (T)	2-2.1
torque, moment of a couple	T	3-12.2
total angular momentum quantum number	j, J	9-20.1
total atomic stopping power	S_a	10-19.1
total cross section	σ_{tot}, σ_T	10-3.2
total ionization by a particle	N_i	10-24.1
total linear stopping power	S, S_l	10-18.1
total macroscopic cross section, total cross section density	Σ_{tot}, Σ_T	10-7.2
total mass stopping power	S/ϱ, (S_m)	10-20.1
total neutron source density	S	10-34.1
transmission coefficient	τ	7-26.3
transport number of ionic substance B, current fraction of ionic substance B	t_B	8-49.1
U		
(unified) atomic mass constant	m_u	9-4.2
upper critical field strength	H_{c2}	13-36.3
V		
velocity	u, v, w, c	1-9.1
velocity (speed) of propagation of electromagnetic waves in vacuum (*in vacuo*)	c, c_0	5-32.1 6-5.1
velocity of sound	c, (c_a)	7-13.1
viscosity, (dynamic viscosity)	η, (μ)	3-21.1
volume	V	1-5.1
volume density of charge, charge density	ϱ, (η)	5-3.1
volume flow rate	q_V	3-27.1
volume flow rate (instantaneous), volume velocity	q, U	7-12.1
volume fraction of substance B	φ_B	8-14.1
volume strain, (bulk strain)	ϑ	3-14.3

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W		
wavelength	λ	2-5.1 6-3.1 7-5.1
wavenumber	σ	2-6.1 6-4.1
weight	G, (P, W)	3-10.2
work	W, (A)	3-24.1
work function	Φ	13-25